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SUMMARY AND ANALYSIS OF WIND TUNNEL TESTS OF SEVERAL STORE CONFIGURATIONS AT HIGH SUBSONIC AND LOW SUPERSONIC SPEEDS

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DEPARTMENT OF AEROSPACE ENGINEERING
AUBURN UNIVERSITY
AUBURN, ALABAMA

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The data obtained from wind tunnel tests of five store configurations have been summarized and documented. Two series of tests were run; force and captive trajectory tests were conducted in late 1974 and pressure tests were completed in early 1975. The purpose of the two series of tests was to help identify a store shape and configuration which would have acceptable release characteristics from a parent aircraft. From the force and captive trajector tests, it was found that all of the store shapes tested had marginal, but acceptable, release characteristics at a Mach number of 0.5, but none had acceptable →

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trajectories at Mach numbers above 1.0. The smaller diameter stores release better than the 16-inch, but are still only marginally acceptable. The pressure tests provided some answers as to the reason for high negative pitching moments on the stores. Large pressure differences exist over the nose regions on all the stores which have a tendency to pitch the store downward. No final acceptable store was identified.

PREFACE

The wind tunnel testing referred to in this report was done in fiscal year 1975 by the Arnold Engineering Development Center (AEDC), Air Force Systems Command (AFSC), Tullahoma, Tennessee. The testing was related to analytical work being done during the period from September 1974 through September 1975 by the Department of Aerospace Engineering, Auburn University, Auburn, Alabama, under Contract Number F08635-75-C-0023 with the Air Force Armament Laboratory, Armament Development and Test Center, Eglin Air Force Base, Florida. Program managers were Captain Visi Arajs followed by Lieutenant Norman Speakman (DLJC). This report constitutes the final report for this contract.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

William F. Brockman

WILLIAM F. BROCKMAN, Colonel, USAF
Chief, Munitions Division

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LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS

C_B	Release coefficient
cg	Center of gravity
C_m	Pitching moment coefficient
C_N	Normal force coefficient
C_p	Pressure coefficient
$C_{p_{cr}}$	Critical pressure coefficient
D	Store diameter
F	Ejector force
I_o, I_{cg}	Mass moment of inertia of store about points O and cg, respectively
L	Store length
m	Mass
M, M_∞	Mach number
M_o	Moments about point O
MV	Maximum volume
q	Dynamic pressure
R_g	Store radius of gyration
R/L	Store radius to length ratio
s	Projected frontal area of store
t	Time
W	Weight
X	Distance from store nose to
X/L	Longitudinal station

LIST OF ABBREVIATIONS, ACRONYMS, AND SYMBOLS (CONCLUDED)

X_O	Distance from cg to rotation point O
X_T	Distance from cg to tail
Z_{cg}	Displacement of cg
α	Angle of attack of model support system
ϕ	Roll angle
$\Delta\theta$	Pitch of store with respect to model support system
θ	Angle of store centerline with respect to horizontal

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SECTION I

INTRODUCTION

The aerodynamic interference of stores as mounted on a triple ejector rack (TER) has been the subject of theoretical and experimental investigation by Auburn University (References 1 through 5) for several years under contract with the Air Force Armament Laboratory, Eglin AFB, Florida. This report is a summary and analysis of the related wind tunnel tests which were conducted at AEDC (Reference 6), Tullahoma, Tennessee, during the fiscal year 1975.

Two series of tests were run; force and captive trajectory tests were run in December 1974 and pressure tests were run in February 1975. The tests were run in the 4-foot by 4-foot transonic wind tunnel at AEDC. For each series of tests, five different basic model configurations were used. Detailed drawings of the 10 per cent scale models are shown in Figure 1. In addition to the five store configurations, tests on two fuze shapes were run on the hemispherical nose shaped models to ascertain the effect, if any, of fuze shape on the aerodynamic forces and moments. Two orientations for the cruciform fins, the plus (+) and cross (x) were investigated on several of the model configurations.

For each series of tests, the tunnel Mach numbers were 0.5, 0.8, 0.9, 1.1, and 1.3. Stores were mounted on a triple ejector rack (TER) (for most of the tests) which was attached to a flat plate wing whose planform shape was that of an F-4 aircraft. A sketch of the mounting arrangement is shown in Figure 2. The wing leading edge was semicircular and the trailing edge was machined sharp in order to simulate more closely the real wing. The root of the wing was attached to a large flat plate aligned with the flow direction in the tunnel as shown in Figure 2. The wing, TER, and two dummy stores were assembled as one integral piece which was mounted to the main support system. Angles of attack of the TER assembly used in the experiments were 0.0 and 5.0 degrees.

The third store (on the real aircraft designated as the No. 1 store) was mounted on a six-degree-of-freedom sting of the captive trajectory system (CTS). For the force test, a six-component balance was used from which the force and moment data were obtained.

In order to position the No. 1 store in the carriage position, touch wires were placed on the TER. Positioning of the active No. 1 store in the carriage configuration during the test was manually controlled until touch. From this point on the trajectory or grid data were obtained by computer control.

For the force and CTS tests, it was assumed that the rig with the wing and TER assembly would not deflect a significant amount under aerodynamic loads during the test run. This assumption was somewhat in error and difficulties were encountered in placing the No. 1 store in the true carriage position. In addition to inaccuracies in the vertical positioning, problems were encountered when it was observed that for some of the tests the active store was yawed and displaced laterally from its correct carriage position. An occasional correction for the yaw and lateral positioning errors was done during the tests by using a television monitor as a visual guide. However, no accurate techniques were available for positioning the No. 1 store if the wing assembly deflected laterally or yawed under aerodynamic loads during the tests.

The primary difficulty encountered during the tests was the vibration or oscillation of the active store mounted on the sting assembly. Visual estimates of the oscillation frequency range from 5 to 50 cycles per second with amplitudes ranging up to 1/2 inch model scale at the nose of the active store. These dynamic problems were generally severe for small displacements of the active store from the carriage position. In some cases, the oscillations of the model were so severe that carriage positioning of the active store could not be obtained and consequently no carriage data could be taken. In an effort to obtain carriage data, the active store was manually displaced in the z-direction to a position where the oscillations did not cause a store ground; that is, where the active store did not hit adjacent stores during its oscillation cycles. In this manner so-called carriage data were obtained although somewhat in error due to the vertical displacement of the active store.

SECTION II

SIMPLIFIED ANALYSIS FOR ACCEPTABLE RELEASE CRITERION

In an effort to place some quantitative meaning on the wind tunnel tests, a simple acceptable store release criterion was established. At the instant the store is released, there are several forces and moments applied to the store which determine its initial trajectory. These forces and moments are illustrated in Figure 3 where it is assumed that all forces act through the center of gravity (cg). The pitching moment applied to the store tends to pitch the store nose down about the cg which tends to rotate the tail upward. If the tail and fins do indeed translate upward, they are likely to impact other store fins or tail assemblies and cause structural damage. While the aerodynamic moments tend to pitch the tail upward, other forces applied at the cg tend to translate the cg downward. In the carriage configuration, the aerodynamic normal force is generally positive (or up) while the weight and ejector force are down. The net result is that the store translates down and pitches nose down (tail up) about some point near the aft end of the store as illustrated in Figure 3. As an acceptable release criterion, it is desired that the tail not translate up, so that the effect of the nose down pitching and the downward cg translation causes the store to rotate about some point 0 such that

$$|X_0| \geq |X_T| \qquad (1)$$

That is, it is desired that the rotation point 0 at the instant of release be either at the tail or, better yet, behind the tail of the store.

If point 0 moves very little in the early release motion, the force equation in the z-direction is

$$\Sigma F_z = m\left[\frac{d^2Z}{dt^2}\right]_{cg} = C_N qs - (W+F) \qquad (2)$$

Integrating equation (2) with $\dot{Z} = dZ/dt = 0$ and $Z=0$ at $t=0$ yields

$$mZ_{cg} = [C_N qs - (W+F)]\,\frac{t^2}{2} \qquad (3)$$

or

$$\frac{2Z_{cg}}{t^2} = \frac{(C_N qs - W-F)}{m} \qquad (4)$$

Summing moments about point 0 yields

$$\Sigma M_0 = (C_N qs - W-F)\ X_0 + C_m qsD = I_0 \frac{d^2\theta}{dt^2} \tag{5}$$

Integrating equation (5) with $\theta = d\theta/dt = 0$ and $\theta=0$ at $t=0$ yields

$$I_0\ \theta = ((C_N qs - W-F)\ X_0 + C_m qsD)\ \frac{t^2}{2} \tag{6}$$

Now if θ is small, as will be the case immediately after release, it may be assumed that

$$\theta \simeq \frac{Z_{cg}}{X_0} \tag{7}$$

Combining equation (6) and equation (7) and rearranging yields

$$\frac{2Z_{cg}}{t^2} = \frac{X_0 qs}{I_0} \left\{ \left[C_N - \frac{W+F}{qs} \right] X_0 + C_m D \right\} \tag{8}$$

Equating equations (4) and (8) yields

$$\left[C_N - \frac{W+F}{qs} \frac{1}{m} \right] = \frac{X_0}{I_0} \left\{ \left[C_N - \frac{W+F}{qs} \right] X_0 + C_m D \right\}$$

which may be rearranged as

$$X_0{}^2 + \left\{ \frac{C_m D}{C_N - \frac{W+F}{qs}} \right\} X_0 - \frac{I_0}{m} = 0 \tag{9}$$

Now

$$I_0 = I_{cg} + m\ X_0{}^2$$

Equation (9) then becomes

$$X_0 = \frac{I_{cg}}{m} \left\{ \frac{C_N - \frac{W+F}{qs}}{C_m D} \right\} \tag{10}$$

If measurements are taken from the nose of the store, the release criterion, equation (1) then becomes

$$\frac{\frac{F+W}{qs} - C_N}{-C_m D} \geq \frac{L-X_{cg}}{R_g^{\,2}} \qquad (11)$$

where R_g is the store radius of gyration.

For this analysis, it is assumed that the average ejector force is 1200 pounds and that the weight of each respective store is

M-117-----------750 pounds
M-117 Mod ------750 pounds
16-in. MV-------800 pounds
14-in. MV-------625 pounds
14-in. MV-------465 pounds

It is convenient to rearrange equation (11) as

$$\frac{\left[\frac{F+W}{qs} - C_N\right] R_g^{\,2}}{-(C_m D)(L-X_{cg})} \geq 1.0 \qquad (12)$$

Defining the left-hand side as C_B, the acceptable release criterion is for C_B to be greater than or equal to 1.0. Using the carriage data as extrapolated from the force test (to be discussed in Section III) the following table is indicative of the release characteristics of each store shape at the test conditions and for each Mach number tested.

TABLE I. RELEASE CRITERION VALUES

M_∞	C_B				
	M-117	M-117 Mod	16-In. MV	14-In. MV	12-In. MV
0.5	3.03	1.614	3.917	14.97	6.91
0.8	0.733	0.848	1.06	2.43	3.06
0.9	0.77	0.862	0.986	1.55	2.06
1.8	0.467	0.385	0.706	0.672	0.814
1.3	0.43	0.402	*	0.866	1.12

*No data were obtained for this case.

From this table, all of the store shapes have acceptable releases for $M = 0.5$, but release characteristics progressively get worse as Mach number increases. It should be pointed out here that $C_B \geq 1.0$ is the minimum acceptable release parameter. Even though C_B may be greater than 1.0, the pitching moment may be so high that the store will tumble or pitch excessively downward. However, if $C_B \geq 1.0$, the store will not initially impact the other stores near the aft end.

SECTION III

ANALYSIS AND DISCUSSION OF FORCE TEST RESULTS

Tests were conducted using 1/10 scale models of the M-117 bomb (standard and modified boattail) and proposed maximum volume bomb shapes having 16-, 14-, and 12-inch diameters. Details and dimensions of the force models are shown in Figure 1. Also shown in Figure 1.(d) are the FMU-56 and FMU-110 fuze shapes which were used with both the force and pressure models of the maximum volume bombs. Additional details of the test program along with the test data are given in the wind tunnel test report listed as Reference 6.

The analysis of the normal force coefficients, C_N, and the pitching moment coefficient, C_m, are considered more important than others (such as C_A, C_ℓ, etc) for presentation in this report and are covered in some detail in the following paragraphs.

General Discussion of Test Results

Because of the difficulties, as previously explained, in obtaining carriage data it was necessary to extrapolate the data available to the true carriage position. During the test sequence the active store was placed in three vertical displacement positions; namely, Z/D = 0.0, Z/D = 0.5, and Z/D = 1.0. These displacements were not the true displacements but were measured from the Z/D position taken at the beginning of each test cycle. For example, at the beginning of the test cycle, the carriage position taken as Z/D = 0.0 might have been 0.15 diameters away from the true carriage position. Subsequent tests during this cycle also would have been in error by 0.15 diameter such that Z/D = 0.5 actually would have been displaced 0.65 diameter from the true carriage position. Because of these induced position errors the force and moment data were extrapolated to the true Z/D = 0.0, the true Z/D = 0.5, etc. Typical examples of this extrapolation process are presented in Figure 4. From plots of this nature, all data presented on subsequent graphs refer to the true carriage, the true Z/D = 0.5, and the true Z/D = 1.0 positions.

Corrected Force and Moment Test Results

The results for the five store shapes in the carriage position at zero angle of attack are presented in Figure 5. From Figure 5 it may be concluded that the crossed fin orientation probably had a more acceptable release than the plus fin orientation. Calculation of C_R, the release coefficient, (see Section II), also indicates that the crossed fin orientation is better than the plus orientation.

Specific conclusions regarding the relative merits of the M-117 store as compared to the Mod M-117 are difficult to make. It was visually noted, however, that during the tests the oscillations for the Mod. M-117 seemed less severe than the M-117 and consequently better carriage data were obtainable. This observation implies that flow over the Mod M-117 was smoother or less turbulent.

In comparing the M-117 shapes with the maximum volume store shapes, it may be said that smaller diameters such as the 14-inch and 12-inch do exhibit better or more acceptable release characteristics. At higher subsonic Mach numbers, the 14-inch and 12-inch bodies do have the best release characteristics of the stores tested.

In Figure 5.(b) the active store has been displaced to half a store diameter. For all configurations there is some decrease in the nose down pitching moment. Also, one could say that the M-117 shape has a greater pitch-down tendency than either the Mod M-117 or the maximum volume shapes.

Figure 6 shows the effects of pitching the TER and stores to 5 degrees angle of attack. As had been expected, the magnitude of the pitching moments decreased for all configurations; however, no new tendencies for any of the stores are exhibited.

Also, as is shown in Figure 6, the Mod M-117 has somewhat smaller pitching moment characteristics than the M-117 as do the 16- and 14-inch diameter maximum volume stores when compared with the 12-inch diameter stores. Also, the negative pitching moment for the crossed fin orientation is smaller than for the plus fin orientation.

Force Data, Pitch Polar Results

In order to illustrate the changes in pitching moments and normal forces due to displacing the store in the z-direction, the extrapolated or interpolated data was crossplotted as shown in Figure 7 for $M = 0.5$. The data shown is for the 16-inch stores only (M-117, Mod. M-117, and 16-inch maximum volume shapes) since these are representative of all the data. The normal forces decreased and in some cases became negative as the store was displaced while the pitching moments increased as expected. Similar results are found for the other Mach numbers (Reference 6). Although nonlinearities show up in the data in the transonic and supersonic Mach number regime as expected, the variation of the aerodynamic coefficients, C_N and C_m, are essentially linear with $\Delta\theta$ (the difference between pitch angles of the TER and store).

Analysis of Fuze Effect

As previously explained, two fuze shapes were investigated on the 16-inch, 14-inch, and 12-inch maximum volume stores. Typical results of these wind tunnel runs are presented in Figure 8. As a general observation, the configurations with the FMU-110 seem to exhibit reduced nose down pitching moments and thus from aerodynamic consideration are regarded as being better than the FMU-56.

Conclusions from Force Tests

In summarizing the force and moment data, it is difficult to make specific conclusions based on specific store geometry. It can readily be seen that the carriage position pitching moment is strongly dependent on Mach number and weakly dependent on store shape, store diameter, fin orientation or fuse configuration. To define the best store shape and configuration from the wind tunnel data is rather arbitrary. However, the following conclusions are offered.

(a) Decreasing the store diameter seems to enhance acceptable store releases, especially at higher Mach numbers.

(b) The Mod. M-117 seems to have less turbulent flow than the M-117, but does not seem to exhibit better store release characteristics.

(c) Fuze shape has little effect on store release parameters.

(d) The crossed fin orientation seems to be better than the plus fin orientation, especially in the carriage position.

(e) Difficulties with the dynamics of the structural support system in the wind tunnel were probably responsible for much of the scatter and associated inaccuracies in the data. Some of these problems were partially alleviated with extrapolation of the data to the true carriage position.

(f) Practically all the carriage data for moment coefficients fall within a band as shown on Figure 9. As can be seen from this figure, very little can be said concerning any clear trends in the data.

SECTION IV

ANALYSIS AND DISCUSSION OF PRESSURE TEST RESULTS

Theoretical Approach

Detailed discussions and derivations of the theoretical techniques used in predicting the pressure distribution on the active store are presented in References 1 through 5. Consequently, the mathematical analysis will not be presented here. However, the general scheme of the analytical approach is presented.

The free stream store shapes are generated by placing 30 point sources along the centerline of the body. Tangency conditions are met at 30 control points on the surface of the body and the strengths of the 30 sources are computed. Interference effects are handled through an image system where the circle theorem is applied at discrete axial locations in order to preserve the body cross section circularity. Angles of attack are taken into account by placing doublets along the centerline of each body. The effect of the wing and pylon have been evaluated and found to be small insofar as normal force and pitching moment due to the body pressure distribution are concerned. They are therefore neglected in this analysis since in most cases they have minor effects on the release characteristics of the active store. To demonstrate the minor effects that the wing and pylon have on the active store, Figure 10 is a plot of the pressure distribution at $\phi = \pm 90$ degrees (top and bottom) for the M-117. Note that there is little difference between the cases where the wing and pylon are considered and cases where only the other two stores are considered. It was deemed, therefore, that the additional expense and time required to run the computer program including the wing and pylon did not warrant the increased accuracy. Consequently, all theoretical results presented in this report for the pressure tests consider only the three stores and simulated TER.

Subsonic-Transonic Test Results

Theoretical results are computed and compared with the experimental data for the pressure test results for Mach numbers of 0.5, 0.8 and 0.9. In many of these tests, oscillations of the model support sting and the active store support system induced errors into the actual carriage data as they did in the force tests. Consequently, each pressure data point was extrapolated to the true wind-off carriage position, Z/D = 0.0. Very little data were obtained for Z/D = 1.0 because of time limitations in the wind tunnel. Consequently, only data for the carriage position and some data for Z/D = 0.5 are presented.

Since in the transonic speed range, the axial position on the store where the flow first becomes sonic can play an important role in the ultimate load or pitching moment distribution. A brief discussion of this effect follows. The critical pressure coefficient as a function of free stream Mach number is presented in Figure 11. Note that at a Mach number of 0.5, a pressure coefficient of about -2.0 is required before sonic conditions are obtained. However, at M = 0.8, a pressure coefficient of about -0.45 is sufficient to produce local sonic conditions. Consequently, each of the pressure test plots should be examined for the possibility that local sonic or supersonic conditions may exist which may explain the sometimes unusual behavior of the data.

On all the pressure plots, the shape of the body under test is plotted at the bottom of the page. In this manner, changes in body shape may be associated with corresponding changes in the pressure distribution.

The test results for the M-117 and the Modified M-117 bombs in their carriage positions are presented in Figures 12 and 13. In each of these figures, the theory and experiment agree fairly well on the bottom of the active store (ϕ = -90 degrees) where interference effects are minimal, but not quite as good atop the store for increasing Mach number. The overpressure on top of the active store in the vicinity of the nose is not predicted well at all by the theory. This overpressure is caused physically by the near stagnation pressure developed in the region between the other two stores on the TER in front of the bomb rack which holds the No. 1 store in the carriage position. In the mathematical model from which analytical pressures are calculated, the bomb rack is not modeled very well and hence the pressure in this region is not accurately predicted. Present efforts are underway to improve this situation.

The general shape of the pressure curves over the store nose for both the M-117 and the Modified M-117 is very nearly the same. Significant differences do occur between the two store shapes in the vicinity of the aft shoulders where the Modified M-117 has a smooth transition and docile pressure changes which have the effect of preventing flow separation and which help provide higher energy air flow over the fins. The high pitching moments seem to be caused primarily by the high pressure differential on the nose of the store and in this region the two store shapes exhibit the same tendencies. Hence, one is not significantly better than the other.

The carriage data for the 16-inch maximum volume store shape is presented in Figure 14. The other two maximum volume stores, 14-inch and 12-inch diameters, generally exhibit the same pressure distributions as the 16-inch body. The flow over the nose becomes sonic somewhere between M = 0.5 and M = 0.8; probably about M = 0.6. At Mach numbers of 0.8 and 0.9, the flow just aft of the nose is probably supersonic. In Figures 14.(b) and 14.(c) a pressure spike is observed in this region. This is probably due to shock development on the forward portion of the pylon and subsequent rise in pressure. All three store diameters exhibit this characteristic. Flow over the aft section of the stores is generally well behaved and little difference is noted between the three store diameters.

In Figures 15 through 17 the active store has been displaced to $Z/D = 0.5$. In this position the agreement between experiment and theory is much better than that found for $Z/D = 0.0$. The overpressure on the nose exhibited by the stores in the carriage position is decreased and the pressure spike prevalent on the hemispherical stores has almost disappeared.

Supersonic Pressure Test Results

The analytical analysis which is currently available is only valid for subsonic compressible flow so that in this section no theoretical results are shown. Lines are drawn through the experimental points to more clearly illustrate the changes in the pressure distribution along the store. Typical supersonic test results are shown in Figures 18 through 20.

The large pressures on the nose of the stores are even more pronounced for the supersonic Mach numbers which account for the large pitching moments shown in the force tests. The pressure spikes just aft of the nose are still present along with other pressure irregularities. These other irregularities are due to the complex shock structure interaction between the stores and would be very difficult to predict by theory. Other general trends in the data are very much the same for the supersonic runs as for the high subsonic (transonic) runs.

Conclusions from Pressure Tests

Conclusions as to which shape is better (in the carriage configuration) for acceptable store releases from the pressure data are not possible. It can be definitely concluded, however, that the ogive transition on the Modified M-117 and the maximum volume shape do indeed enhance the flow over the fins of the stores.

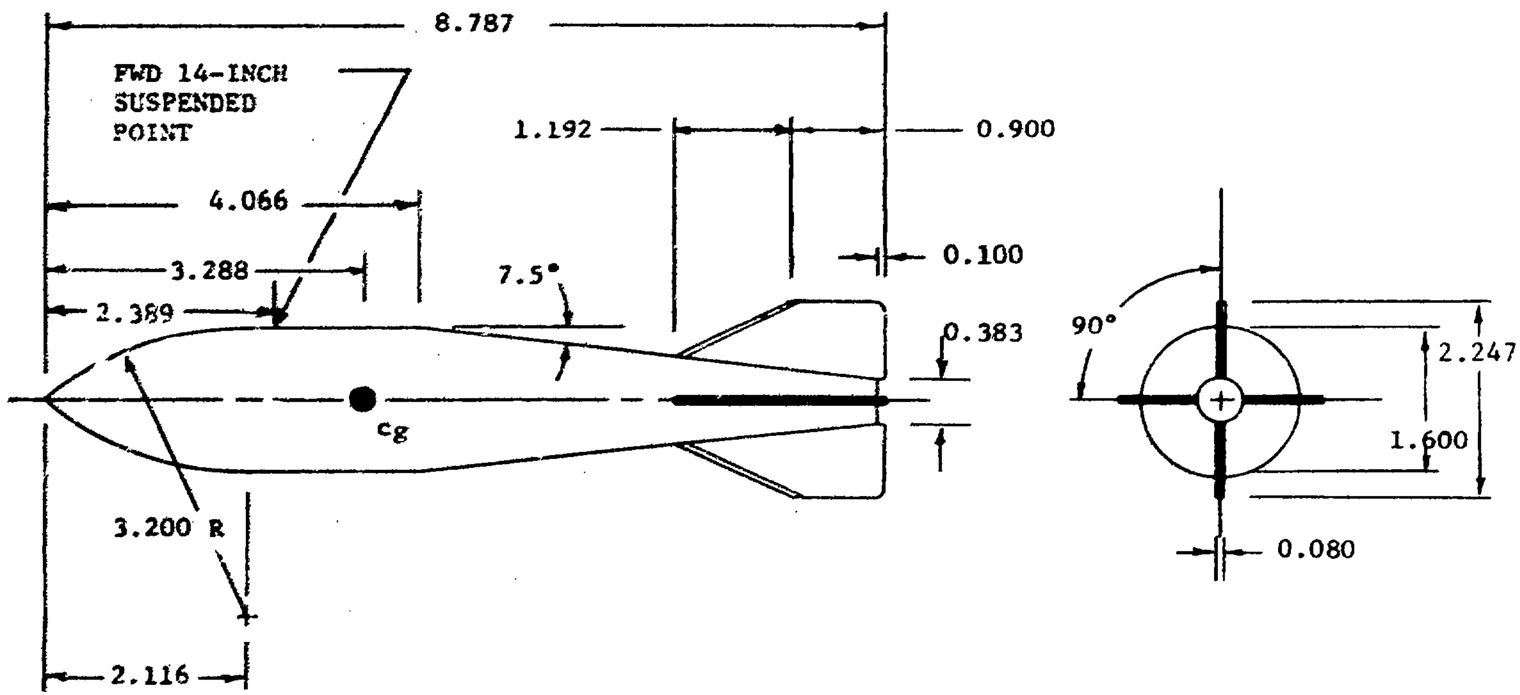
As in the force tests, specific definition of the best store shape from the pressure data is not possible. Several specific characteristics of the various store shapes tested are made; however:

(a) A rather large pressure differential exists on the nose of each of the store shapes which is primarily responsible for the large pitching moments measured in the force tests. This overpressure on the nose is greater on the M-117 shapes than on the maximum volume shapes.

(b) Displacing the store downward in the vertical direction decreases the overpressure, but even at $Z/D = 0.5$ there is a significant pressure difference which still produces high negative pitching moments.

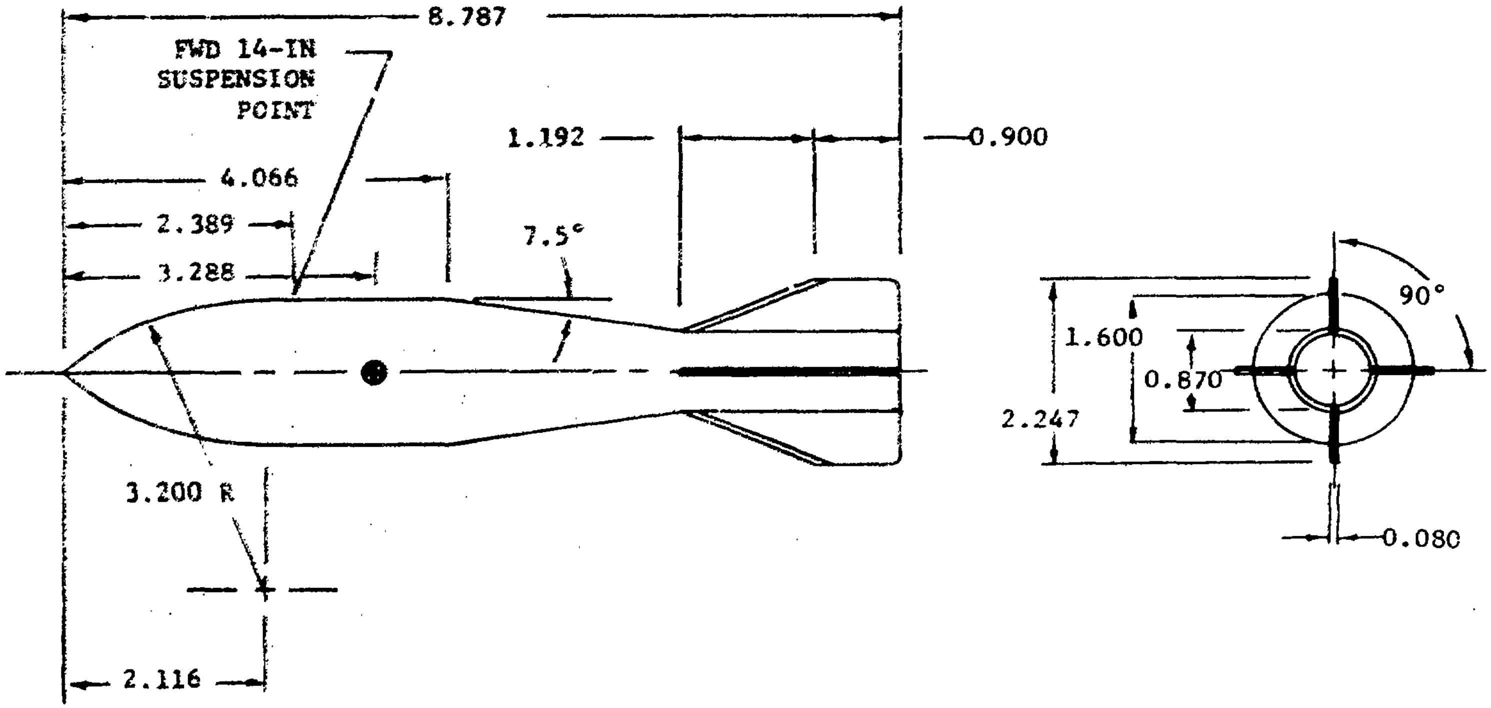
(c) Because of the nose pressure differentials, nose shape is a significant factor in the pitching moment problem with afterbody shape having little effect.

(d) A shock wave probably exists in front of the pylon on the maximum volume shapes at Mach numbers of 0.8 and up. This shock produces a pressure spike which contributes to the nose down pitching moments.



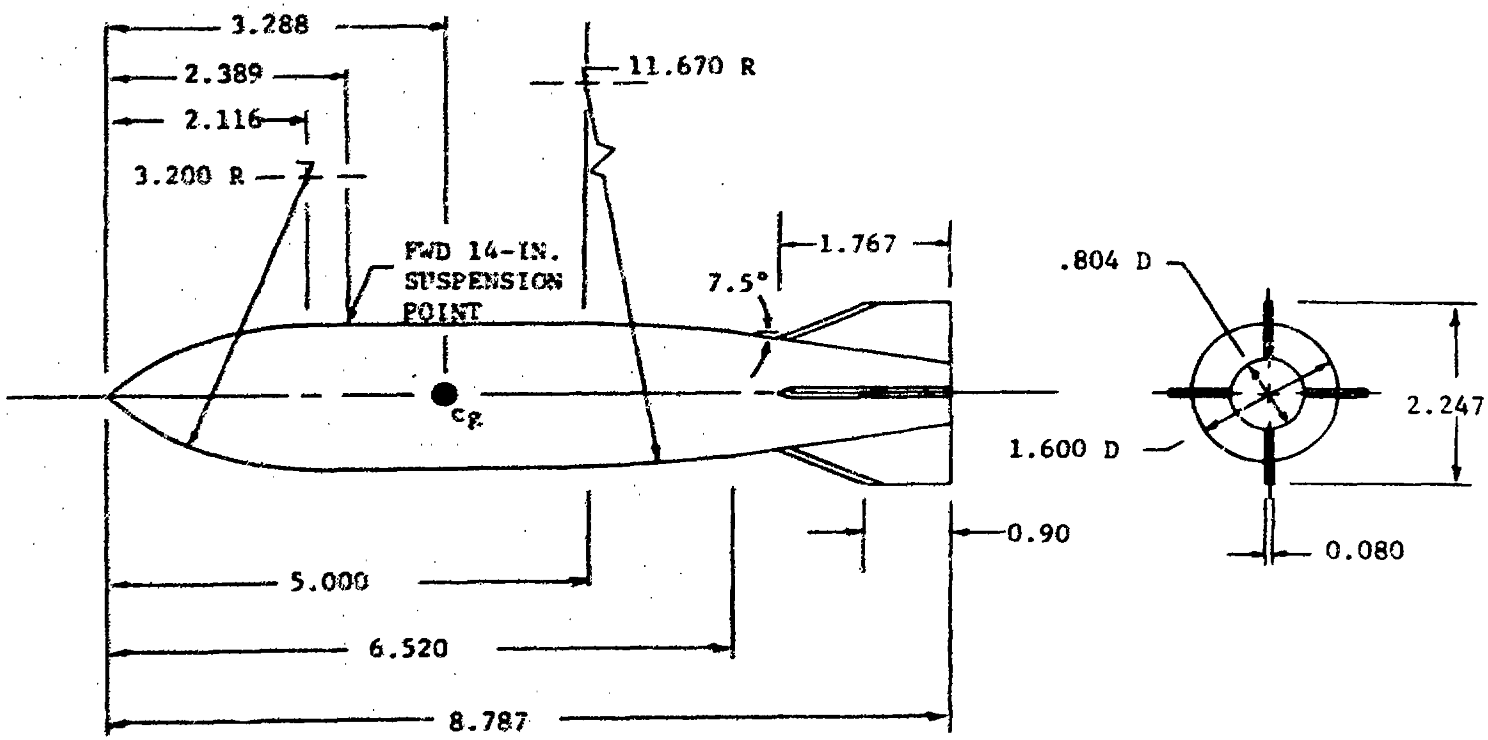
(a) Standard M-117 Bomb Configuration (Dummy)

Figure 1. Details and Dimensions of the Force and Moment Models



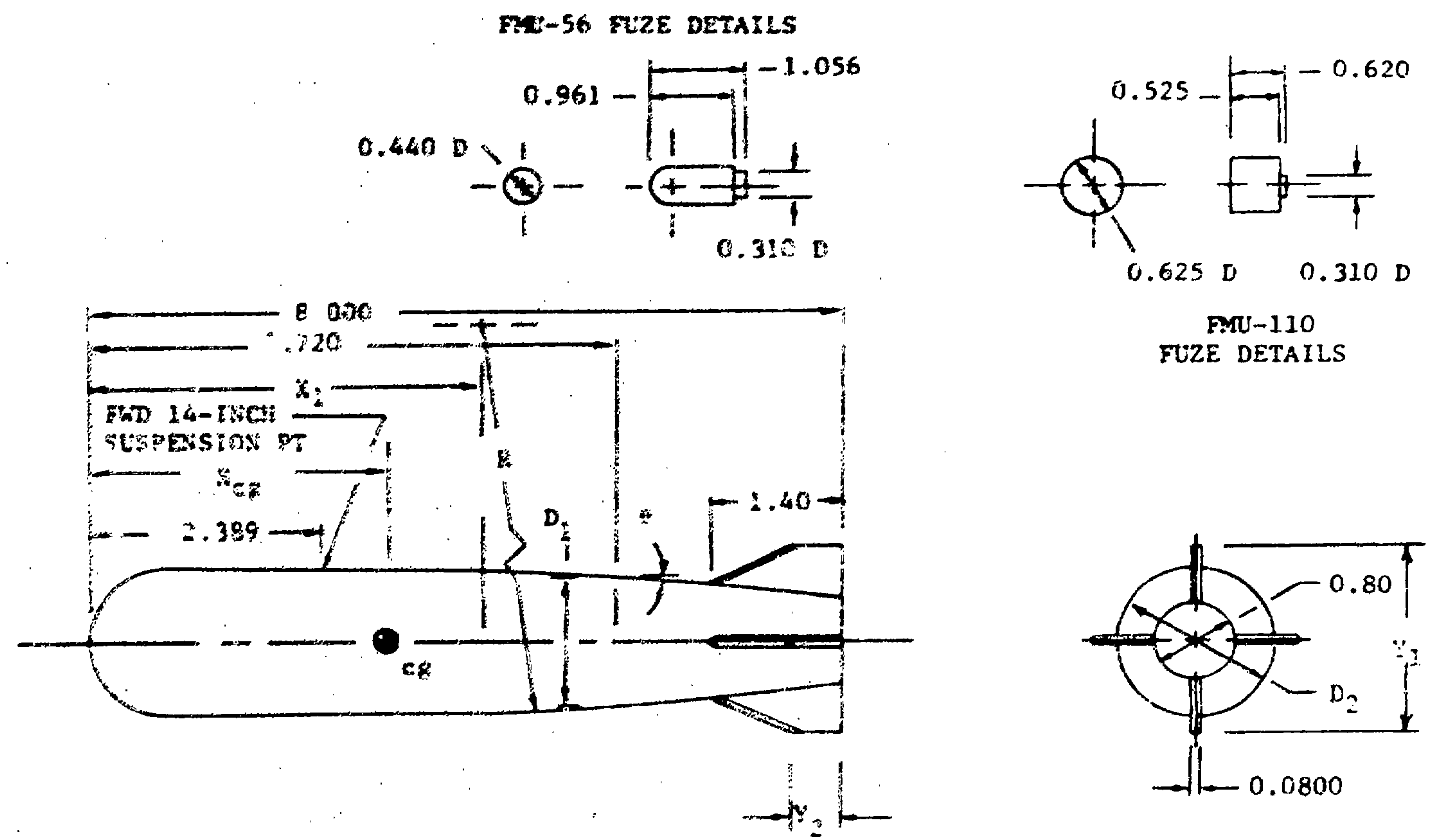
(b) Standard M-117 Bomb Configuration (Instrumented)

Figure 1. (Continued)



(c) M-117 Bomb Configuration with Modified Boattail

Figure 1. (Continued)



MODEL NO.	X_1	X_{cg}	Y_1	Y_2	D_1	D_2	θ	R
16-IN	4.197	36.5	2.200	0.501	1.400	1.600	7.50°	11.67
14-IN	4.184	36.5	2.050	0.551	1.250	1.400	5.63°	15.77
12-IN	4.176	35.0	1.900	0.606	1.099	1.200	3.75°	23.62

(d) Maximum Volume Store Modifications and Fuzes

Figure 1. (Concluded)

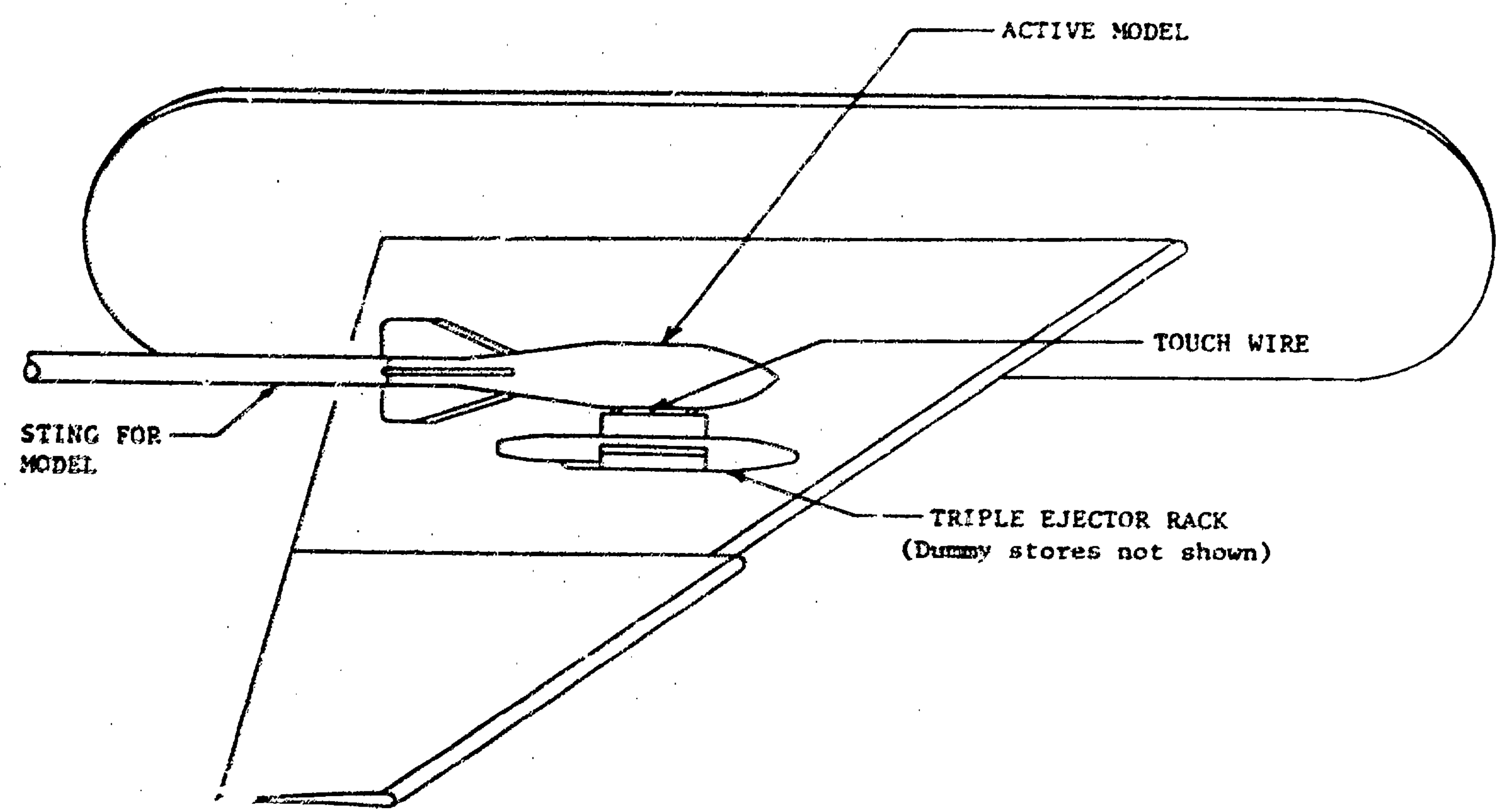


Figure 2. Schematic of Test Apparatus

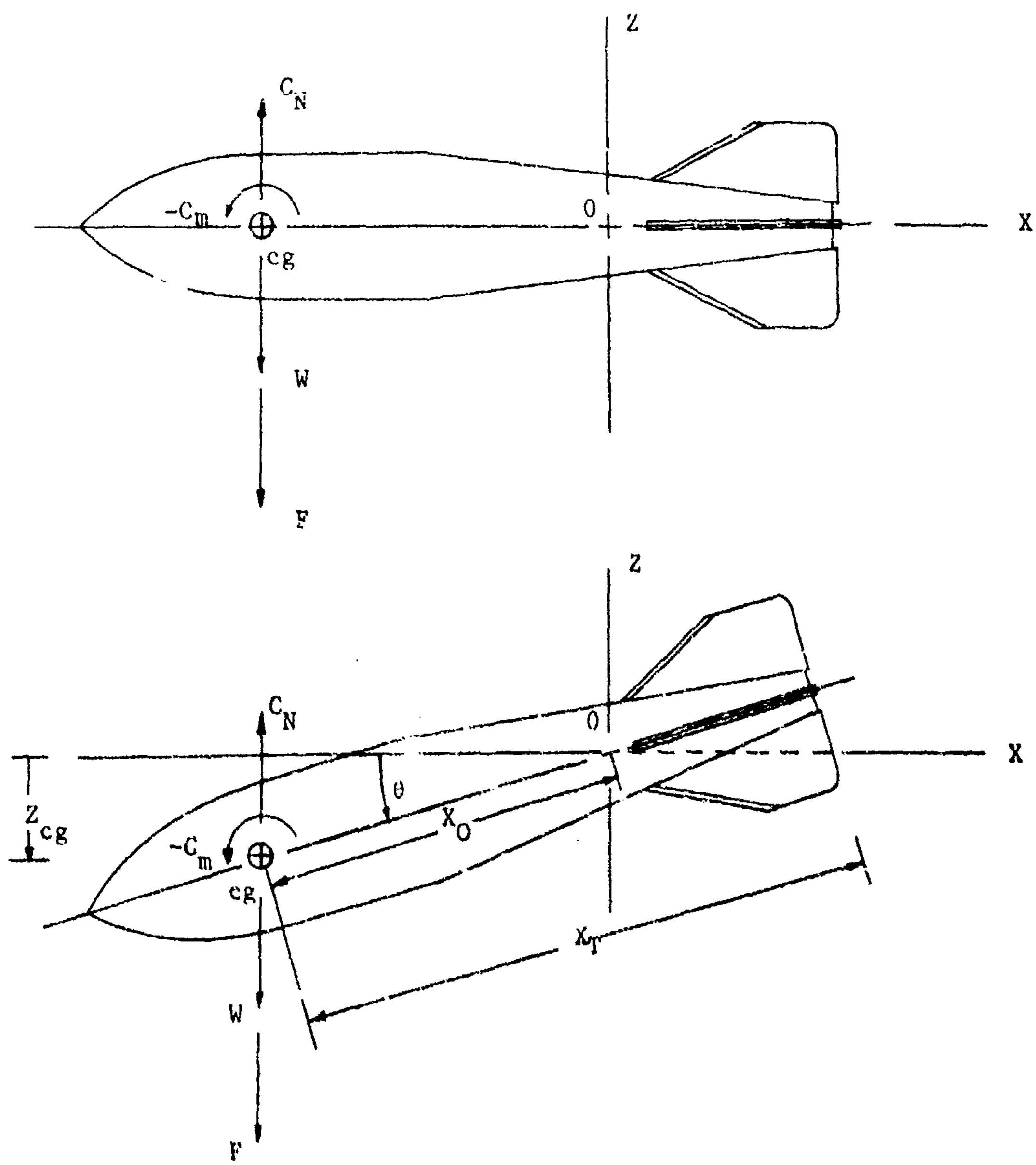
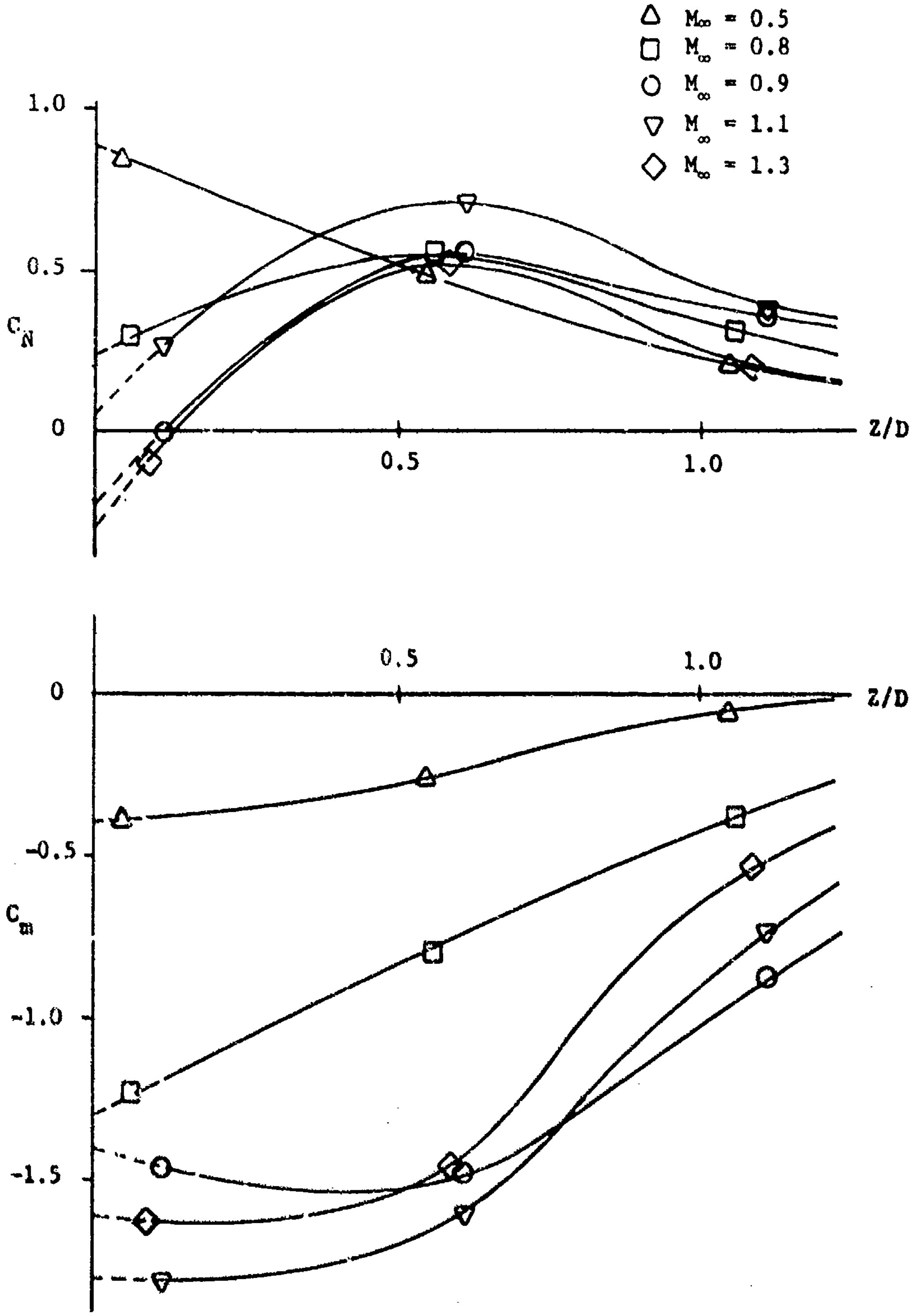
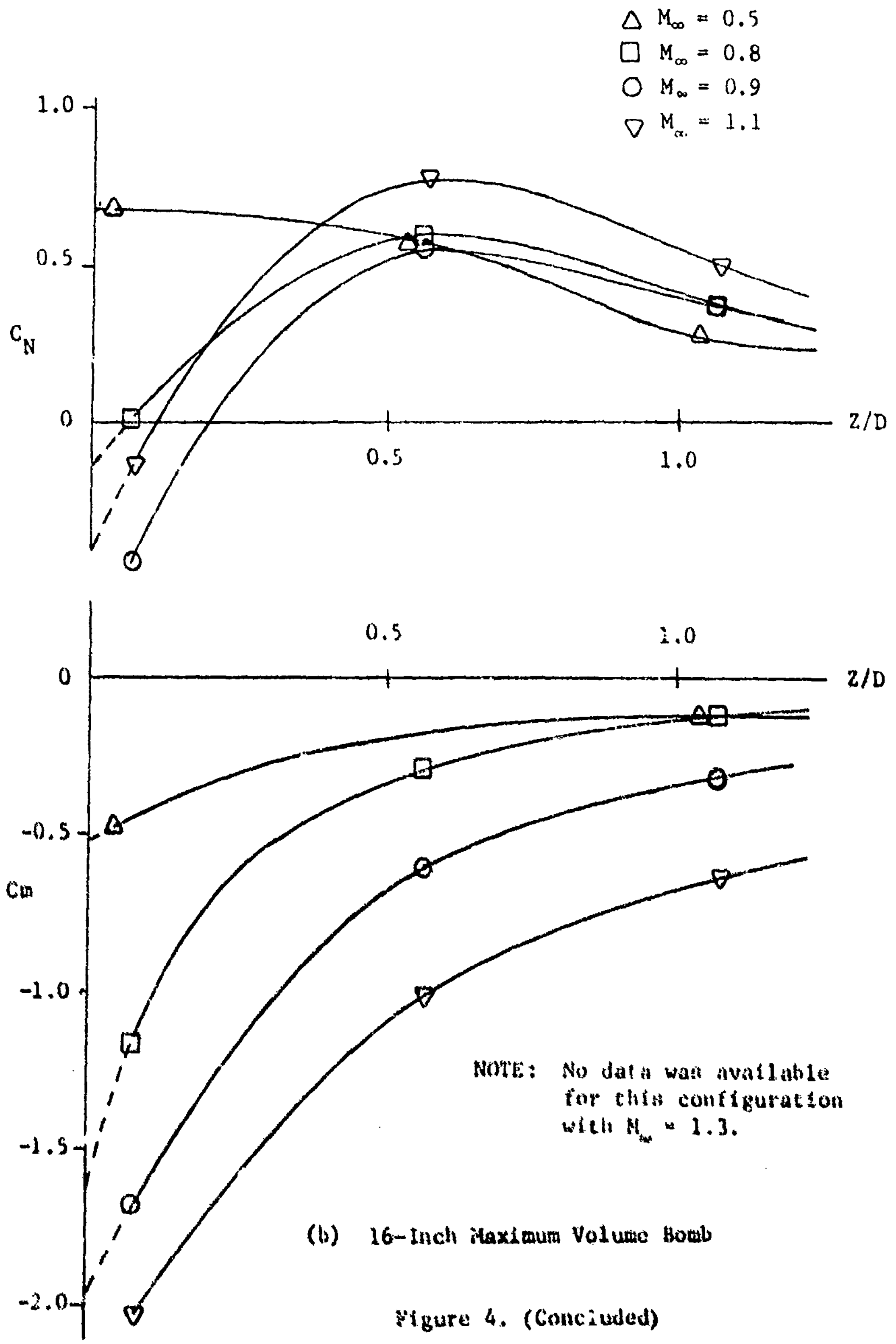


Figure 3. Schematic of Coordinate System and Force System Used in Bomb Release Anrlysis



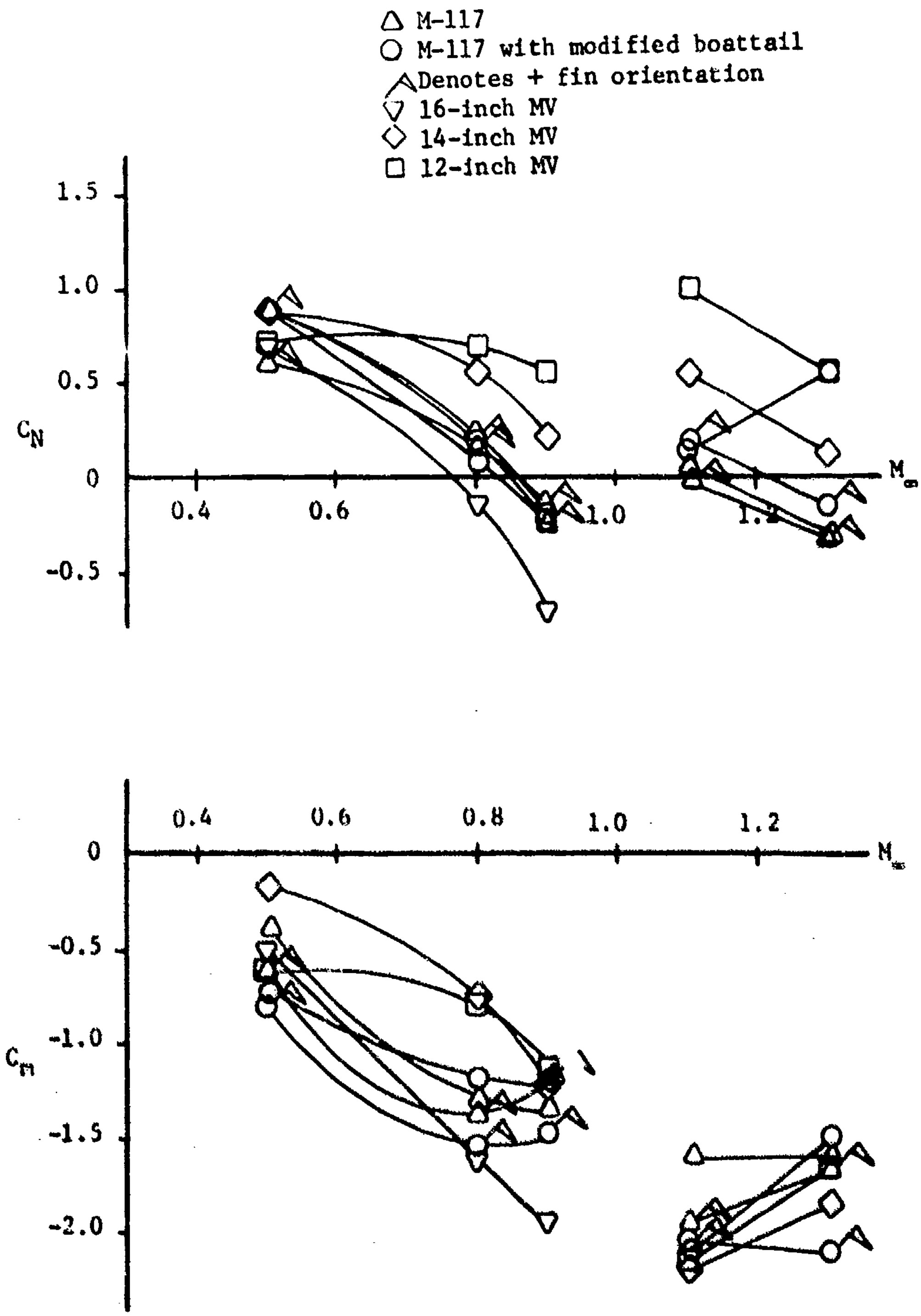
(a) M-117 Bomb

Figure 4. Experimental Force and Moment Coefficients versus Store Displacement for Model in Carriage Position No. 1, $\alpha = 0°$, $\Delta\theta = 0°$, X Fin Configuration



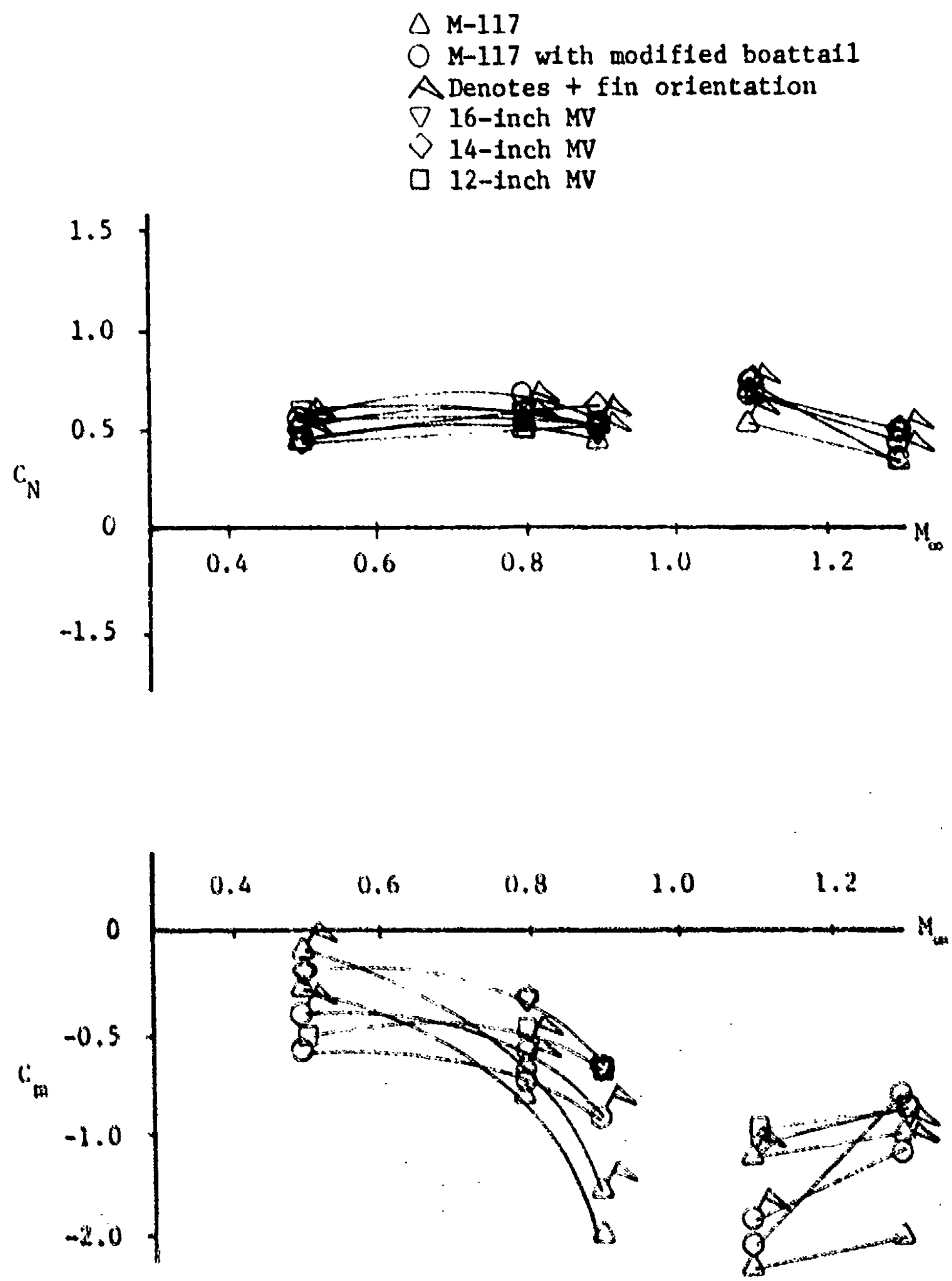
(b) 16-Inch Maximum Volume Bomb

Figure 4. (Concluded)



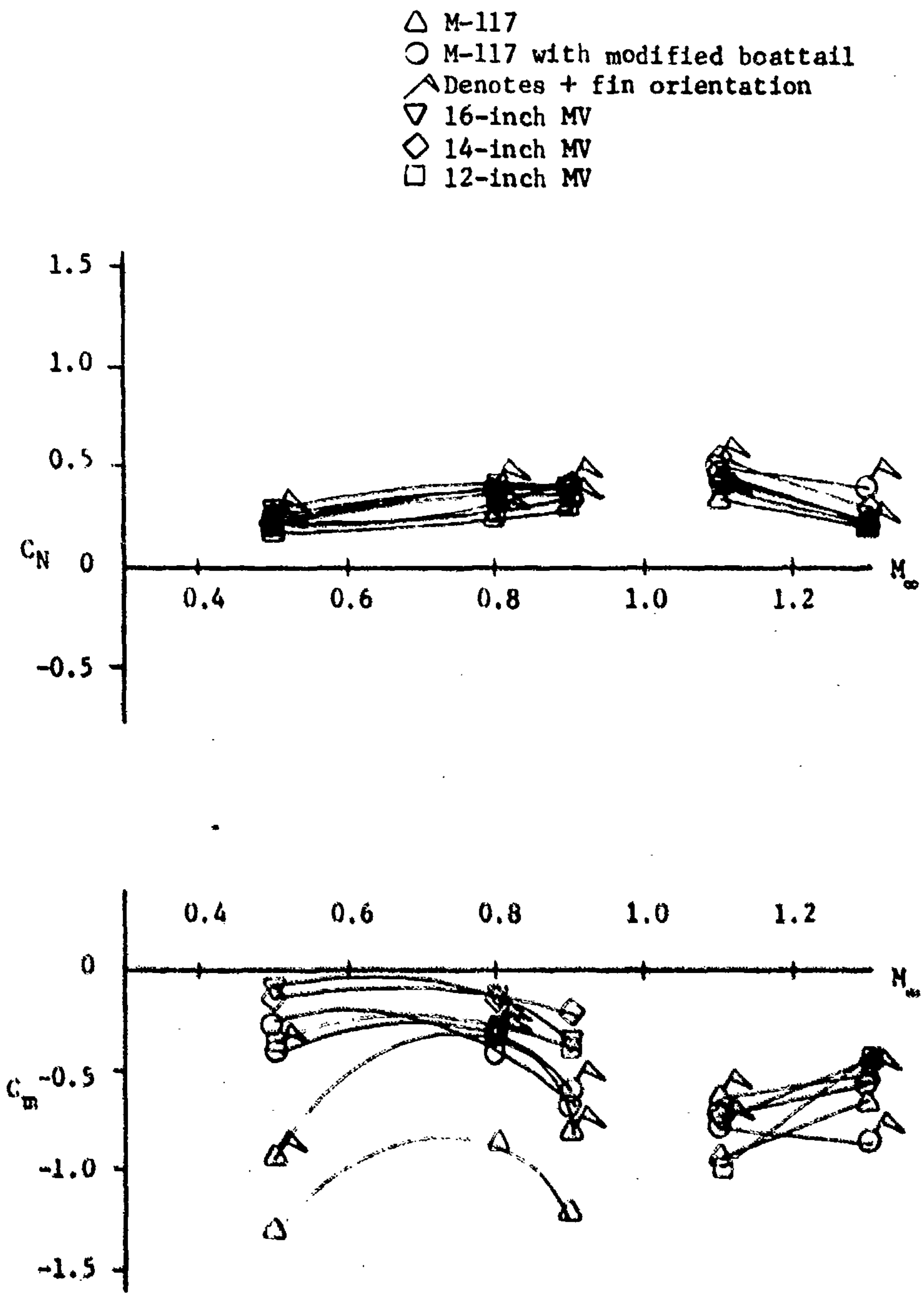
(a) Z/D = 0

Figure 5. Experimental Normal Force and Pitching Moment Coefficients versus Mach Number for Model in TER Carriage Position No. 1, α=0, θ=0°.



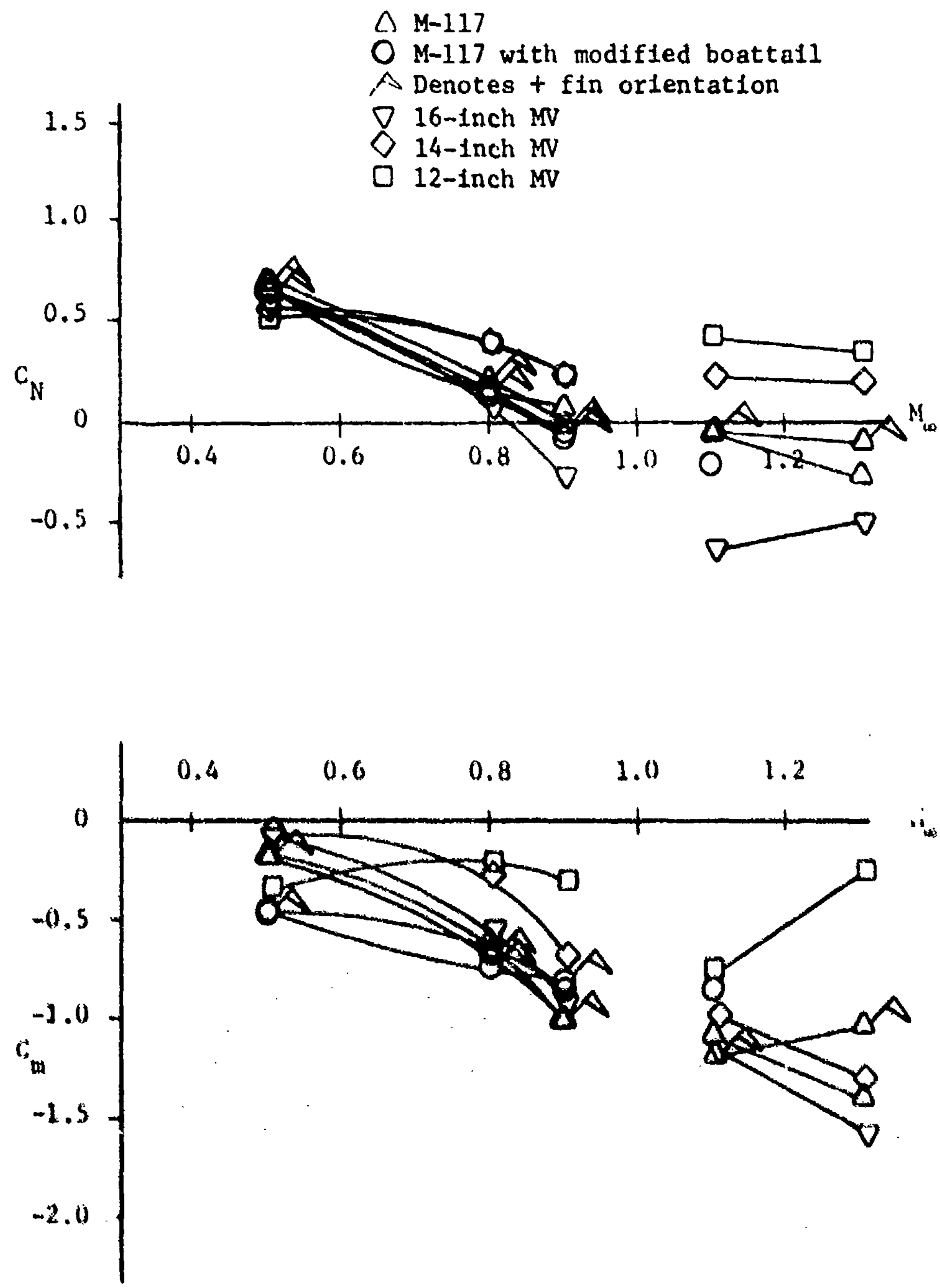
(b) Z/D = 0.5.

Figure 5. (Continued)



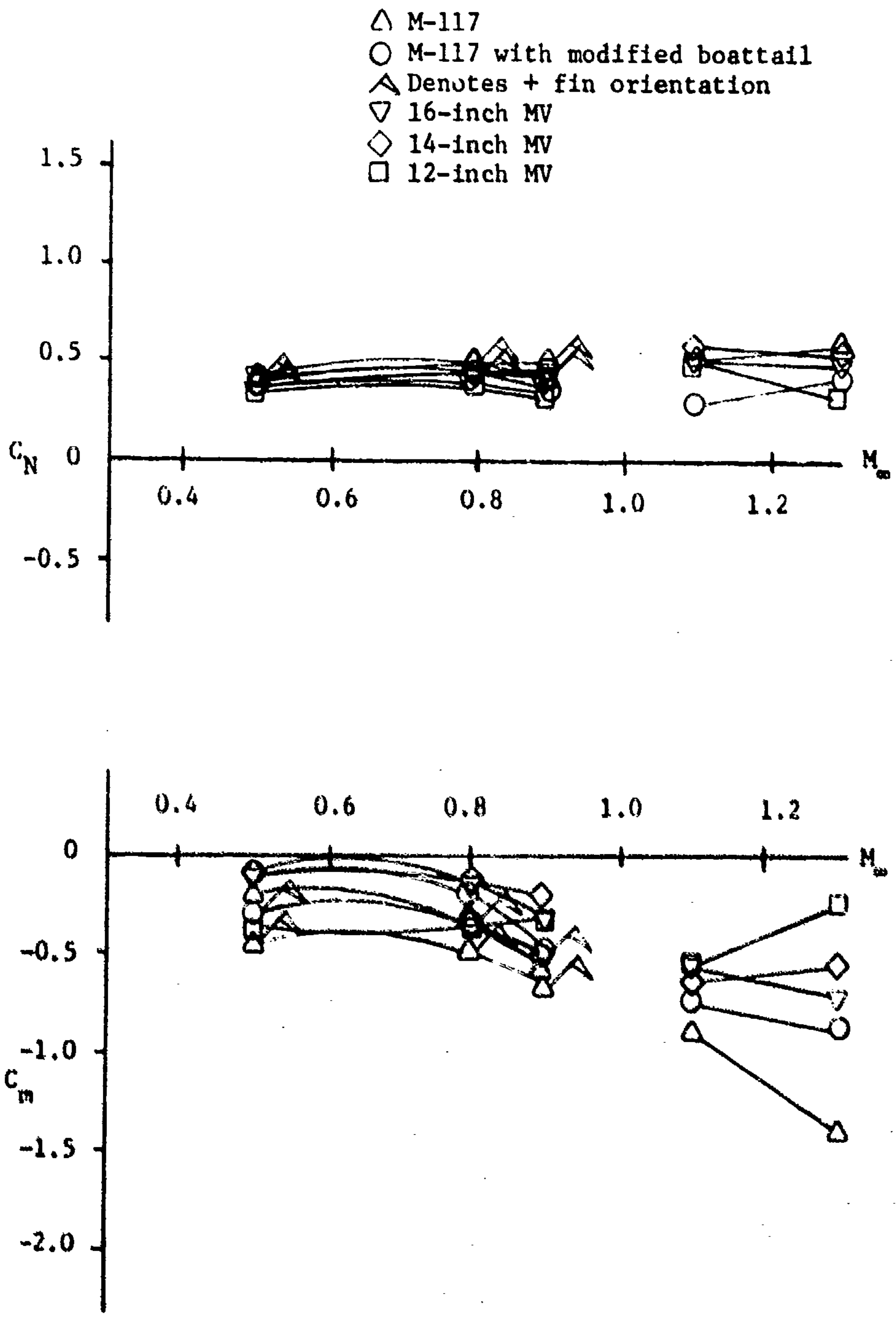
(c) Z/D = 1.0

Figure 5. (Concluded)



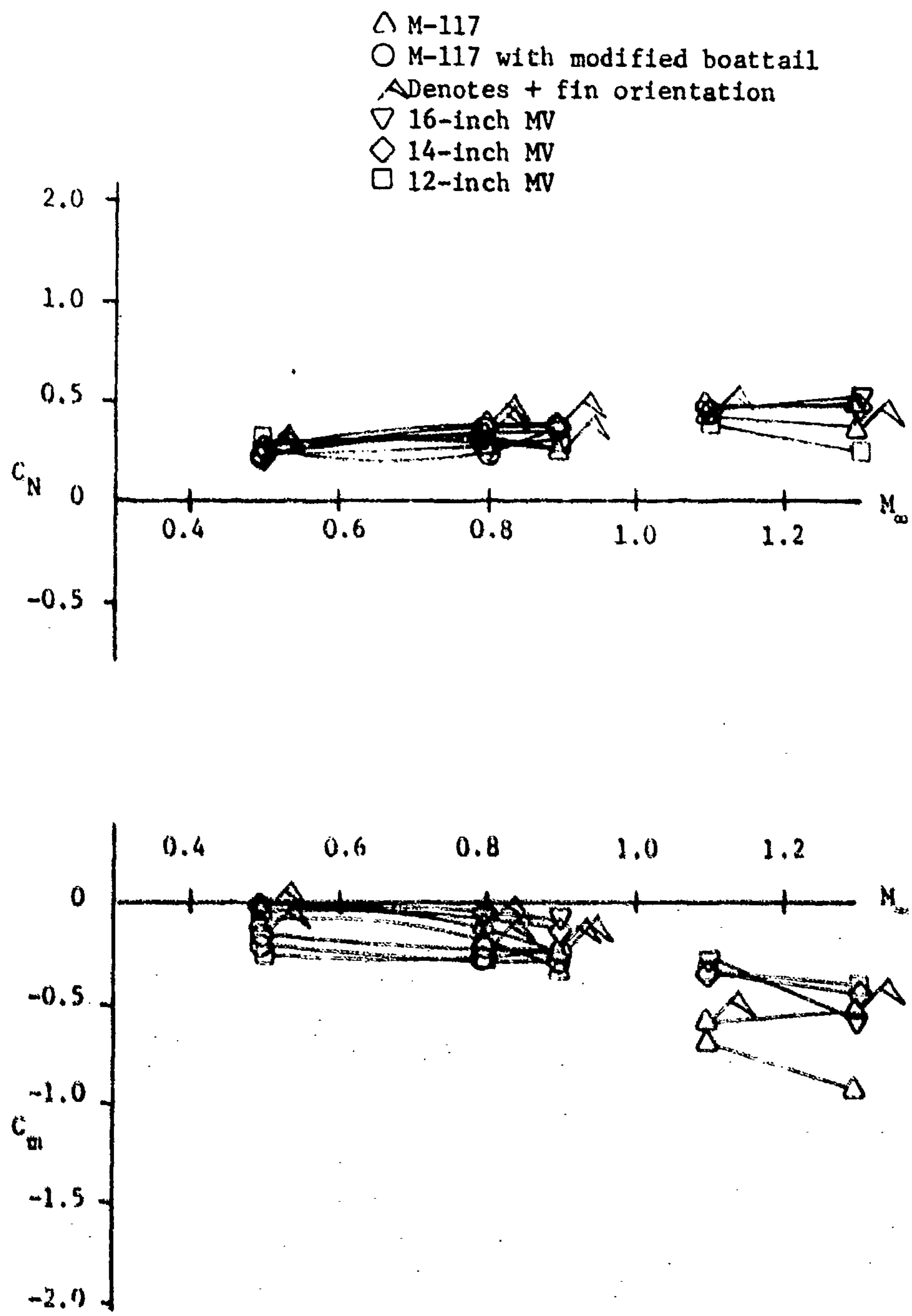
(a) Z/D = 0.0

Figure 6. Experimental Normal Force and Pitching Moment Coefficients versus Mach Number for Model and TER at 5° Angle of Attack. Model in TER Carriage Position No. 1, α=5°, θ=0°.



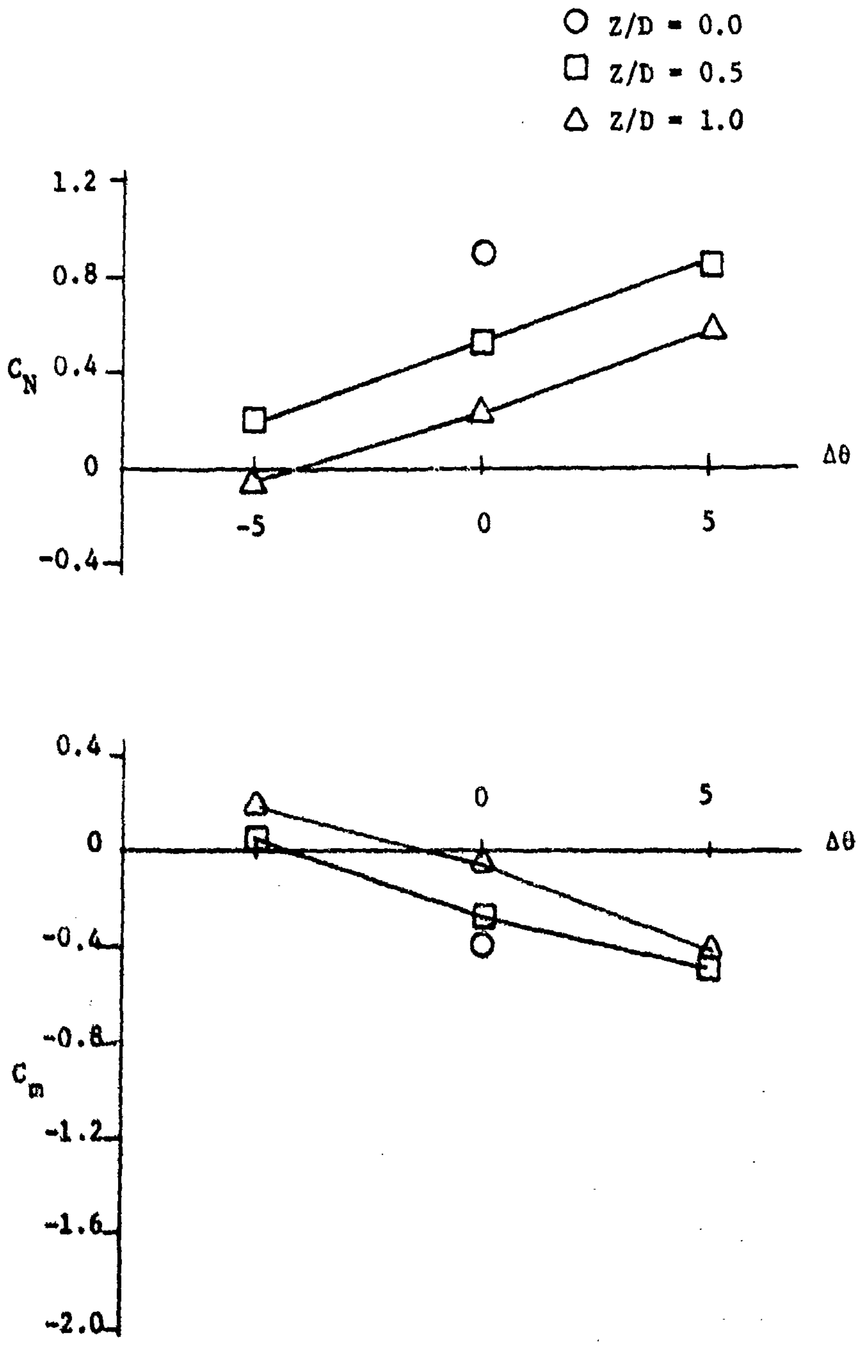
(b) Z/D = 0.5

Figure 6. (Continued)



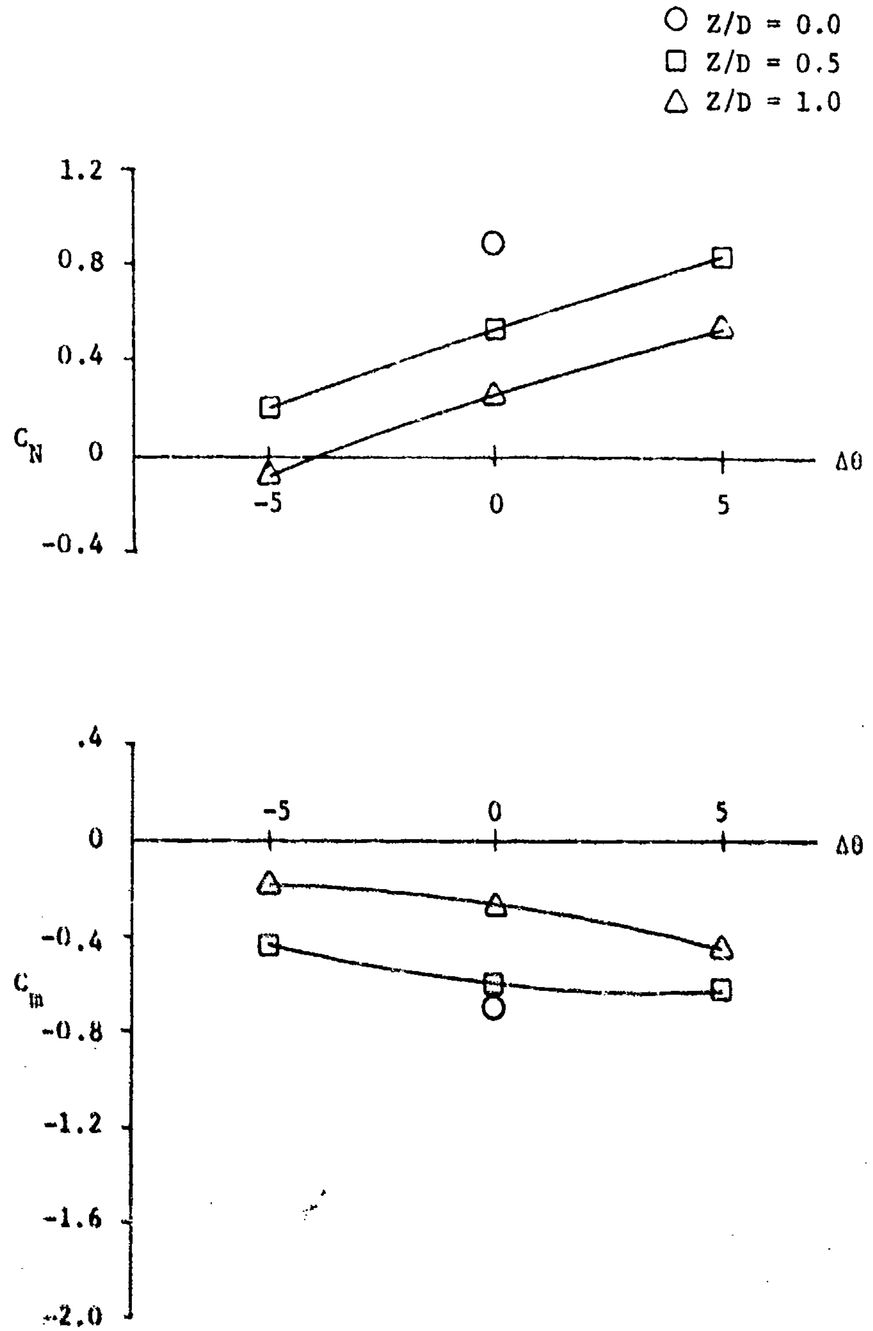
(c) Z/D = 1.0

Figure 6. (Concluded)



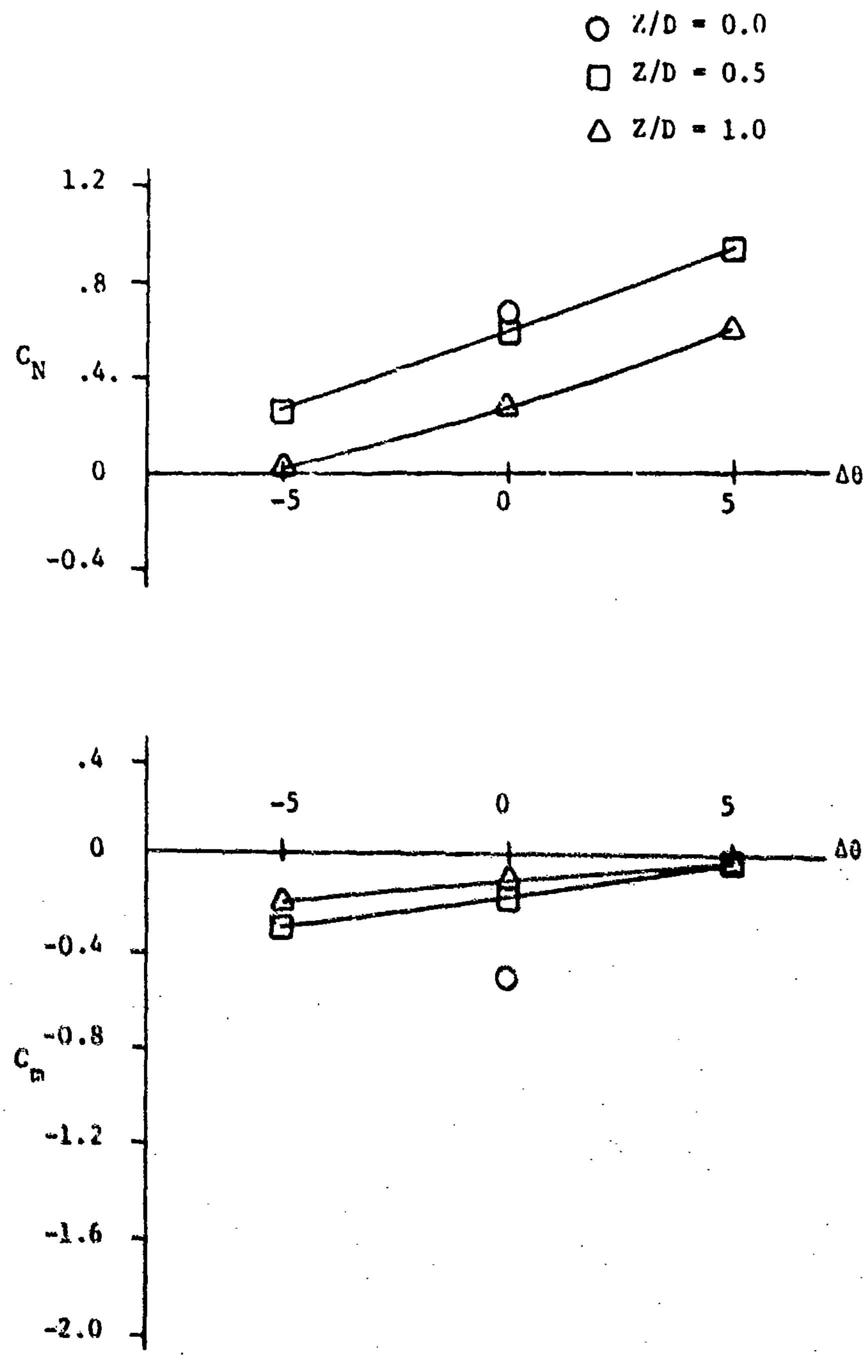
(a) M-117 Configuration

Figure 7. Experimental Normal Force and Pitching Moment Coefficients versus $\Delta\theta$ at $Z/D = 0.0$, 0.5, and 1.0 for Model in Carriage Position No. 1, $\alpha = 0°$, $M_\infty = 0.5$, × Fin Configuration.



(b) Mod M-117 Configuration

Figure 7. (Continued)



(c) 16-Inch Maximum Volume Configuration.

Figure 7. (Concluded)

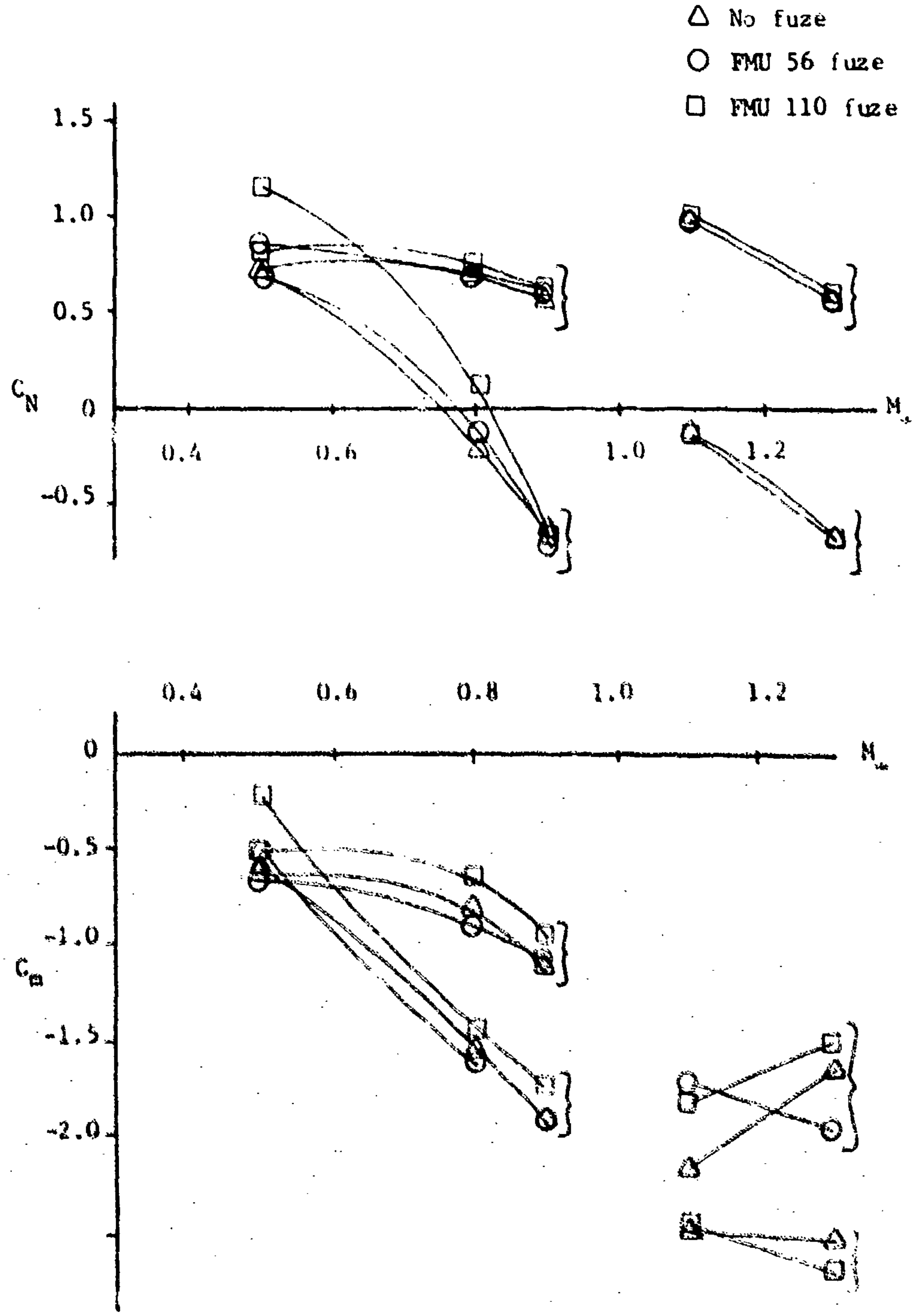


Figure 8. Experimental Normal Force and Pitching Moment Coefficients versus Mach Number for Maximum Volume Bombs Showing Effects of Fuzes. $\alpha=0°$, $Z/D=0.0$, $\phi=0°$, x Fin Configuration.

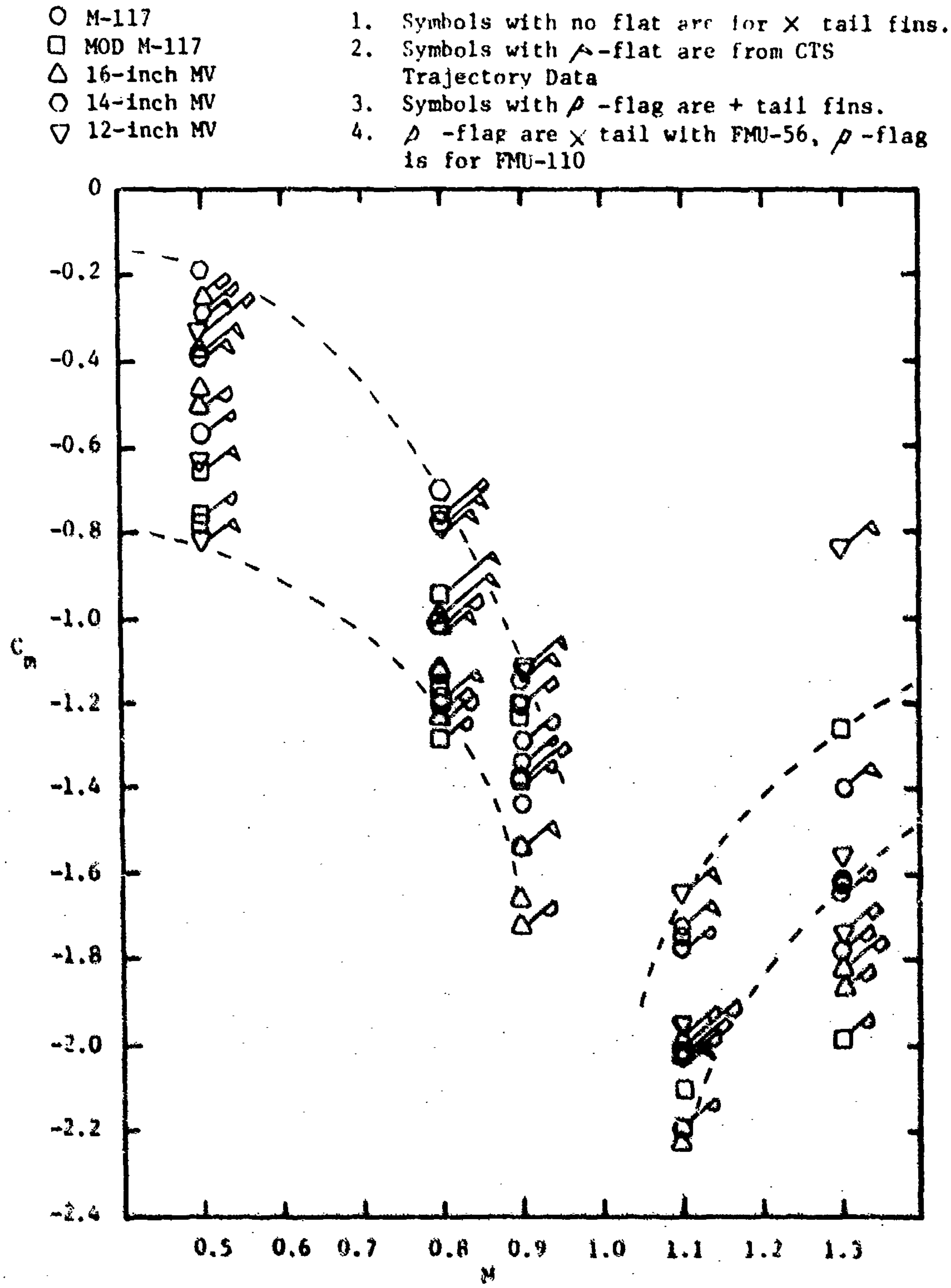


Figure 9. Carriage Loads, C_m, versus Mach Number, M, for Body on Station No. 1 on Loaded Triple Ejector Rack, α=0°

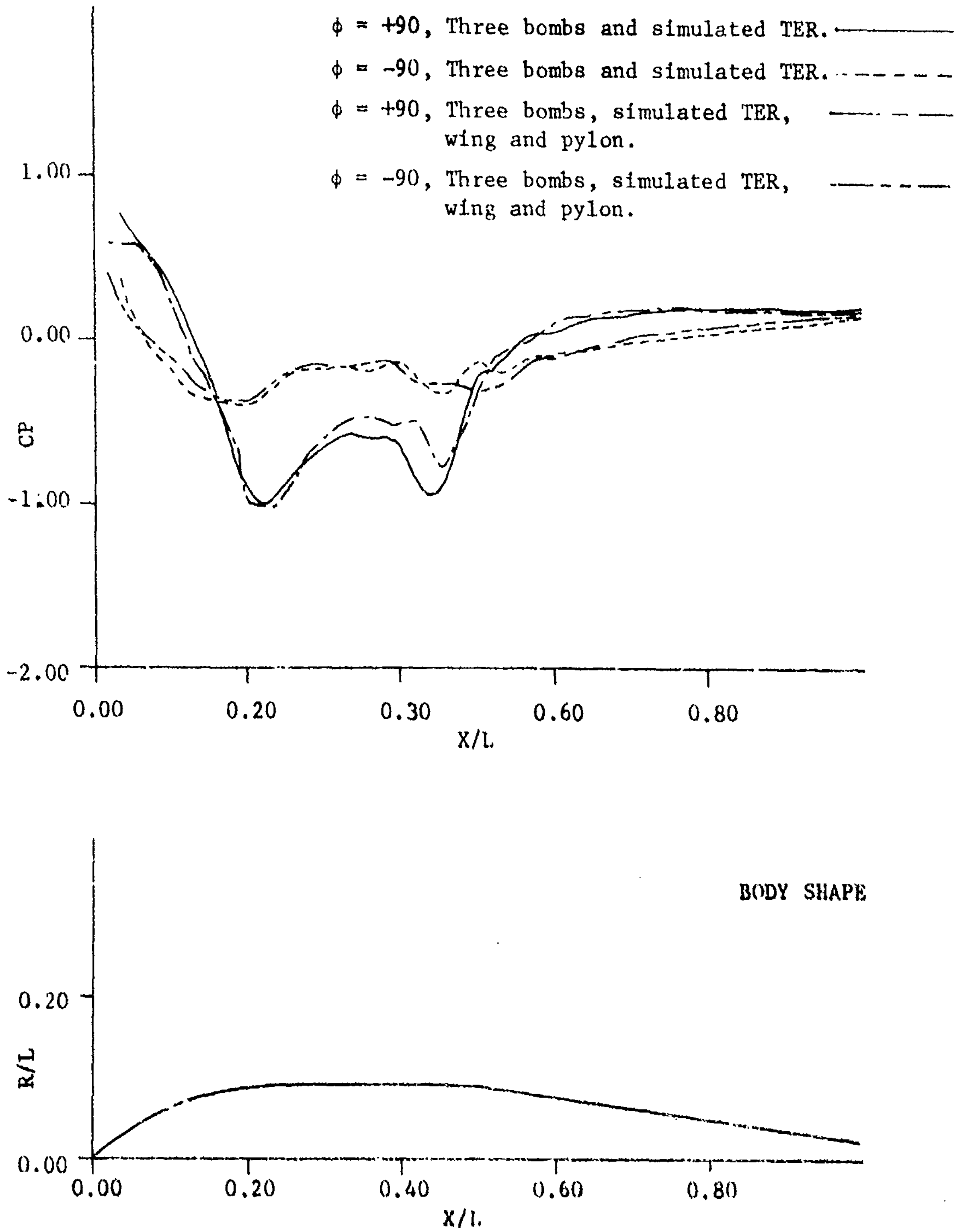


Figure 10. Comparison of Analytical Pressure Distribution for M-117 Bomb on the Inboard Pylon Station of an F-4 Wing at $M = 0.5$, $\alpha = 0.0$.

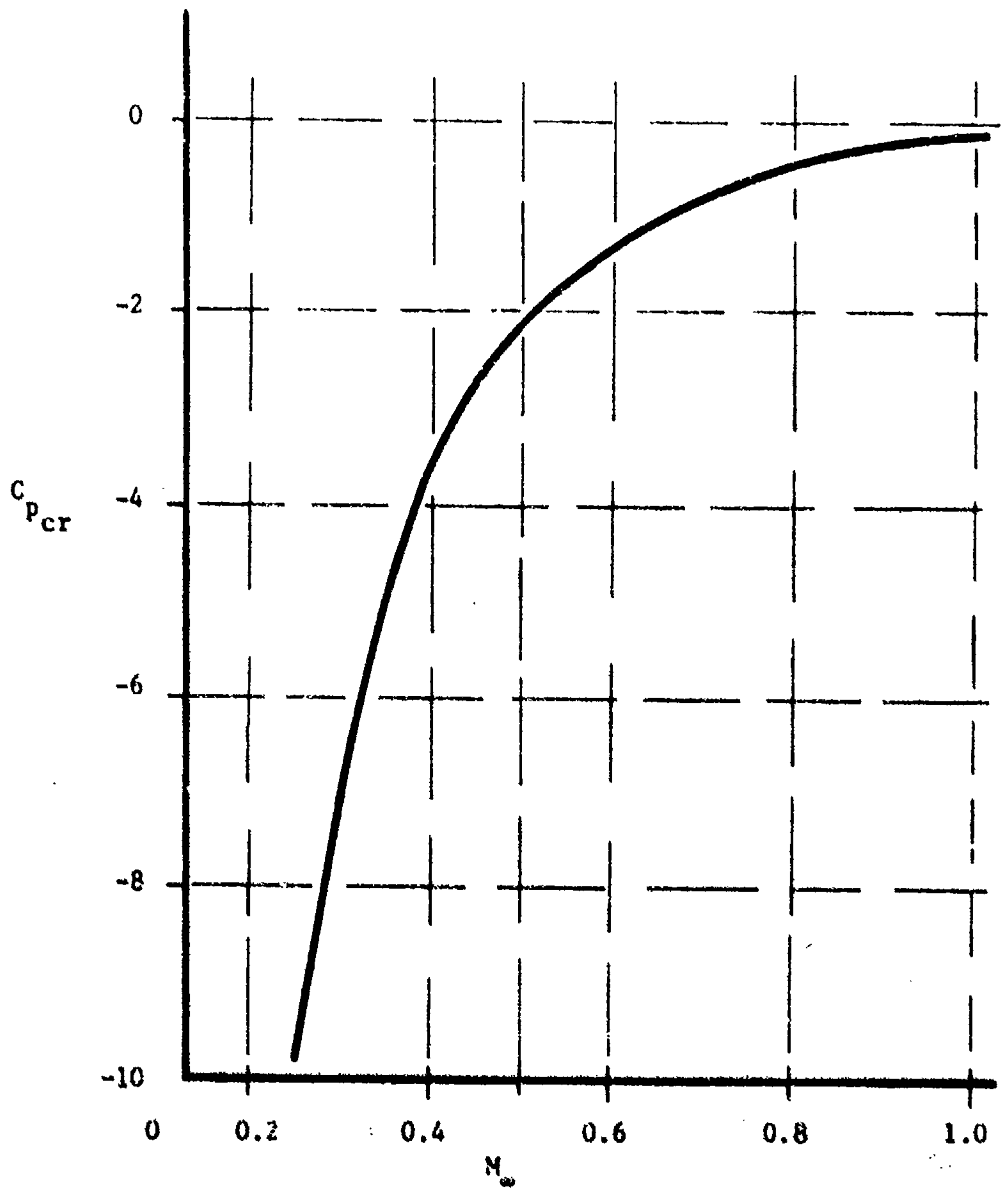


Figure 11. Critical Pressure Coefficient versus Freestream Mach Number

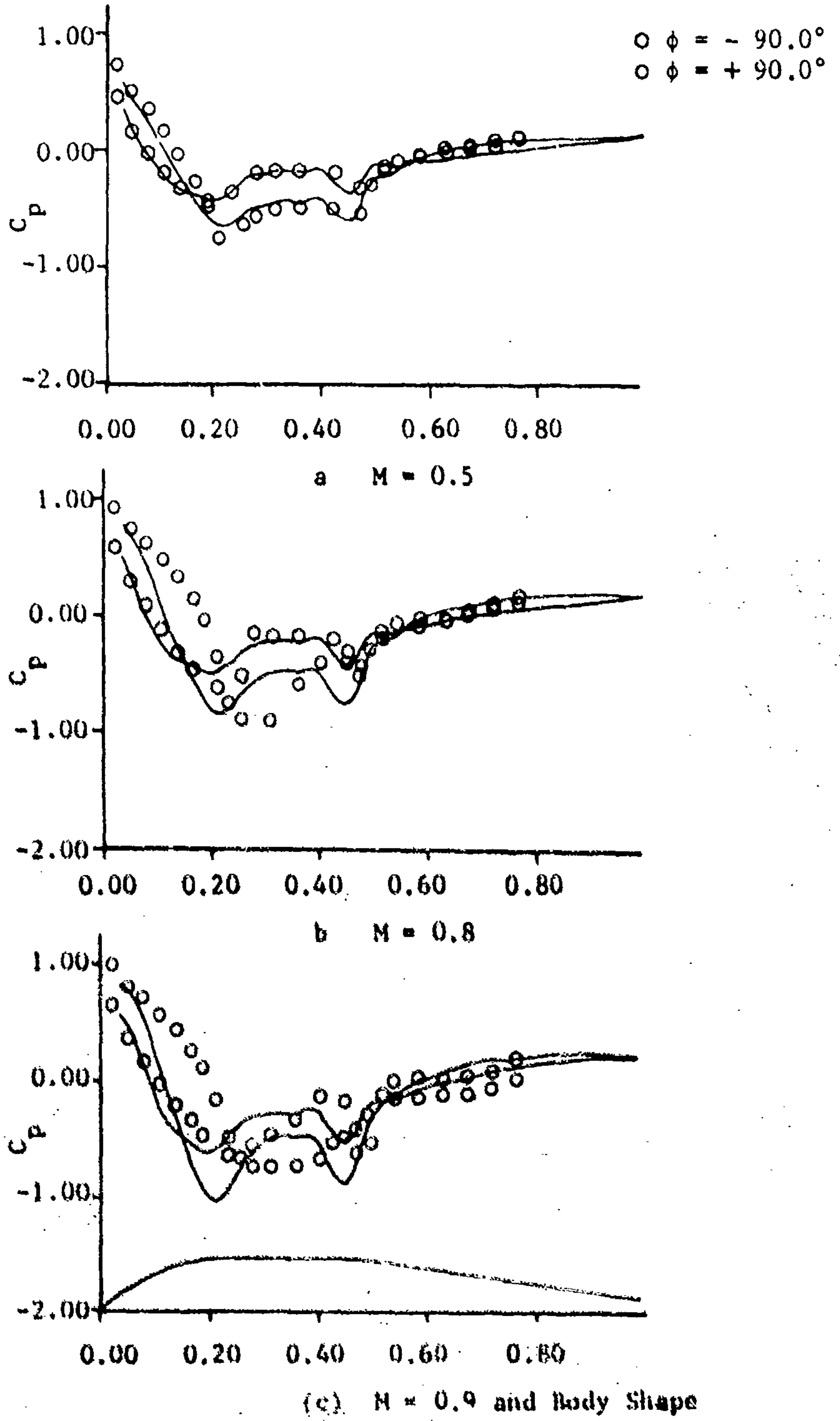
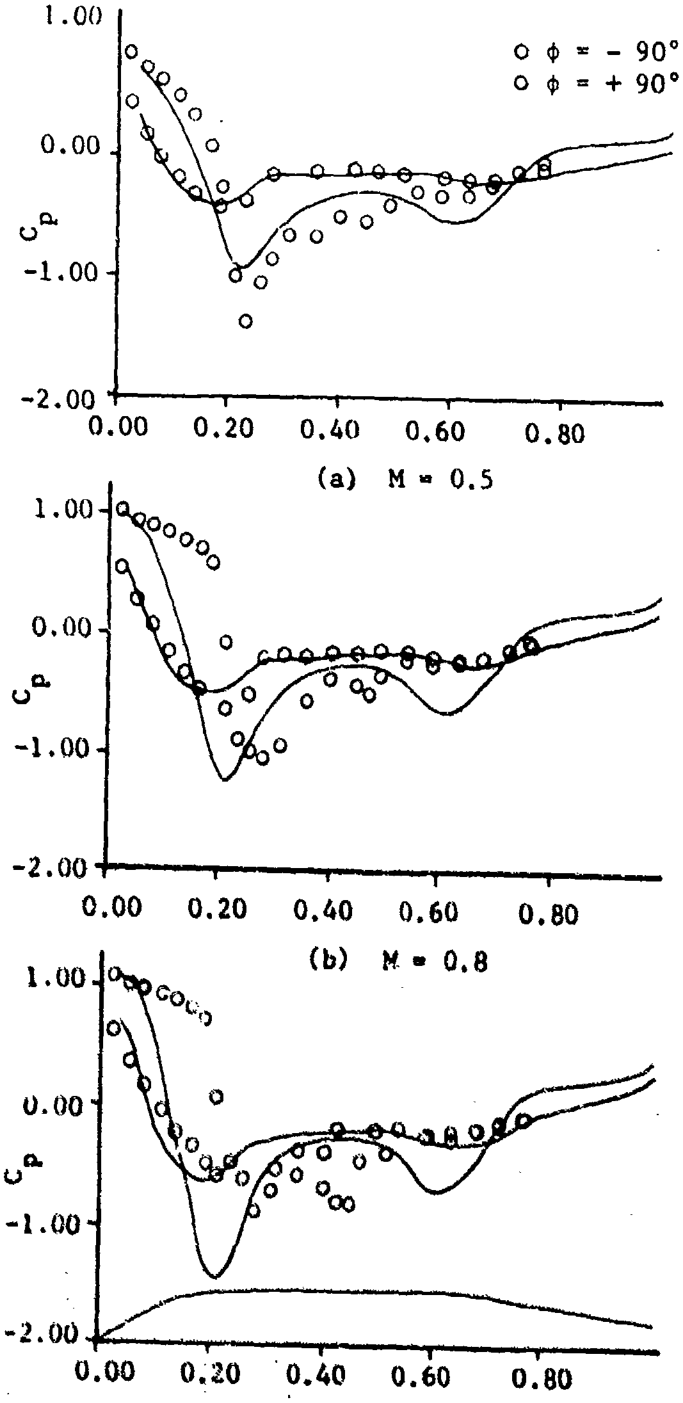
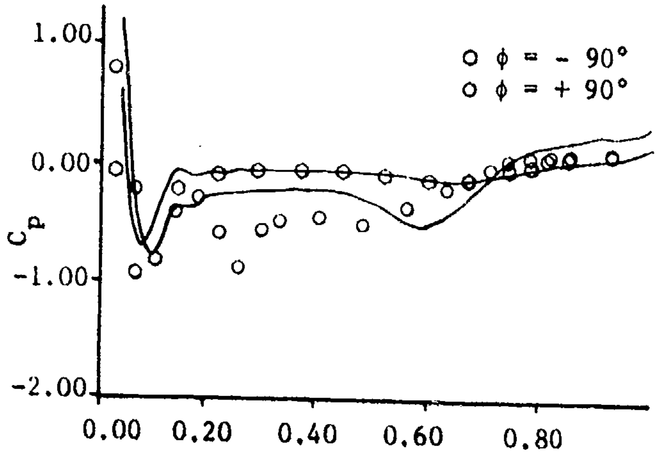


Figure 12. Comparison of Theoretical and Experimental Pressure Distributions for M-117 Bomb in TER Carriage Position No. 1 Z/D = 0.0, α = 0°, θ = 0°.

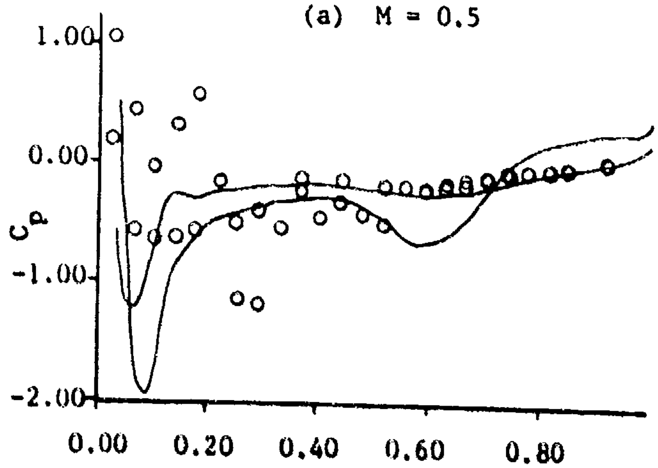


(c) M = 0.9 and Body Shape.

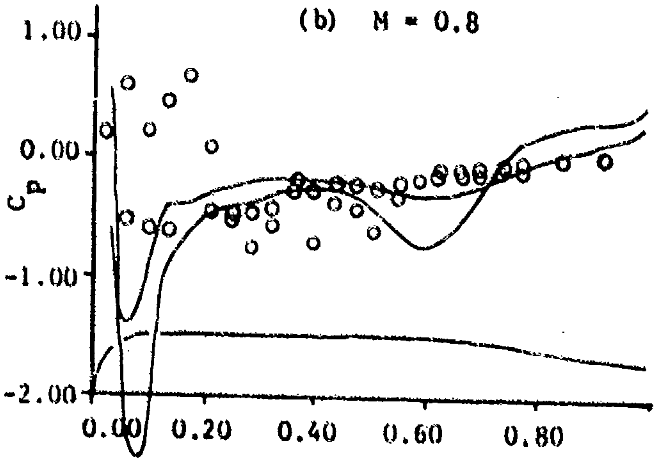
Figure 13. Comparison of Theoretical and Experimental Pressure Distributions for Mod M-117 Bomb in TER Carriage Position No.1, Z/D = 0.0, α = 0°, θ = 0°.



(a) M = 0.5



(b) M = 0.8



(c) M = 0.9 and Body Shape

Figure 14. Comparison of Theoretical and Experimental Pressure Distributions for 16-Inch Maximum Volume Bomb in TER Carriage Position No.1, $Z/D = 0.0$, $\alpha = 0°$, $\theta = 0°$.

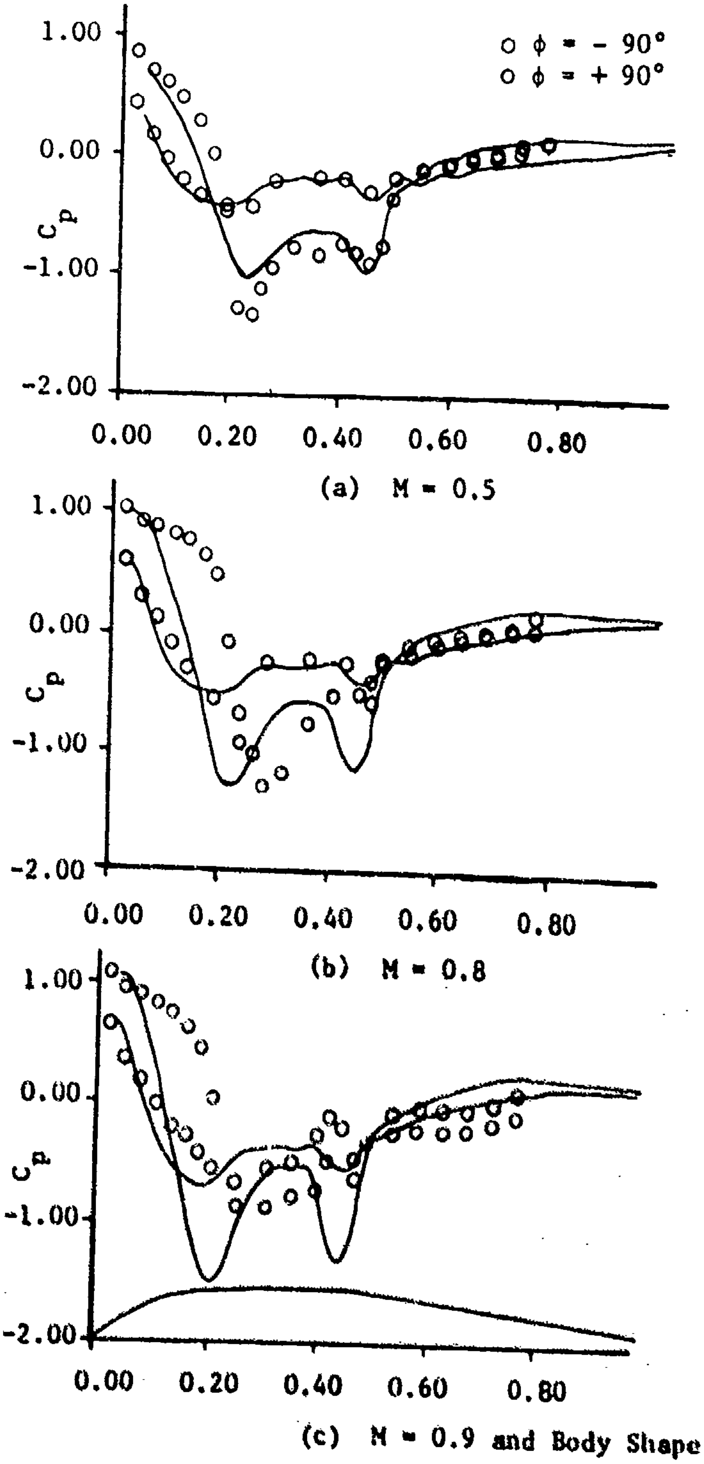


Figure 15. Comparison of Theoretical and Experimental Pressure Distributions for M-117 Bomb displaced to Z/D = 0.5 from TER Carriage Position No.1, α = 0°, θ = 0°.

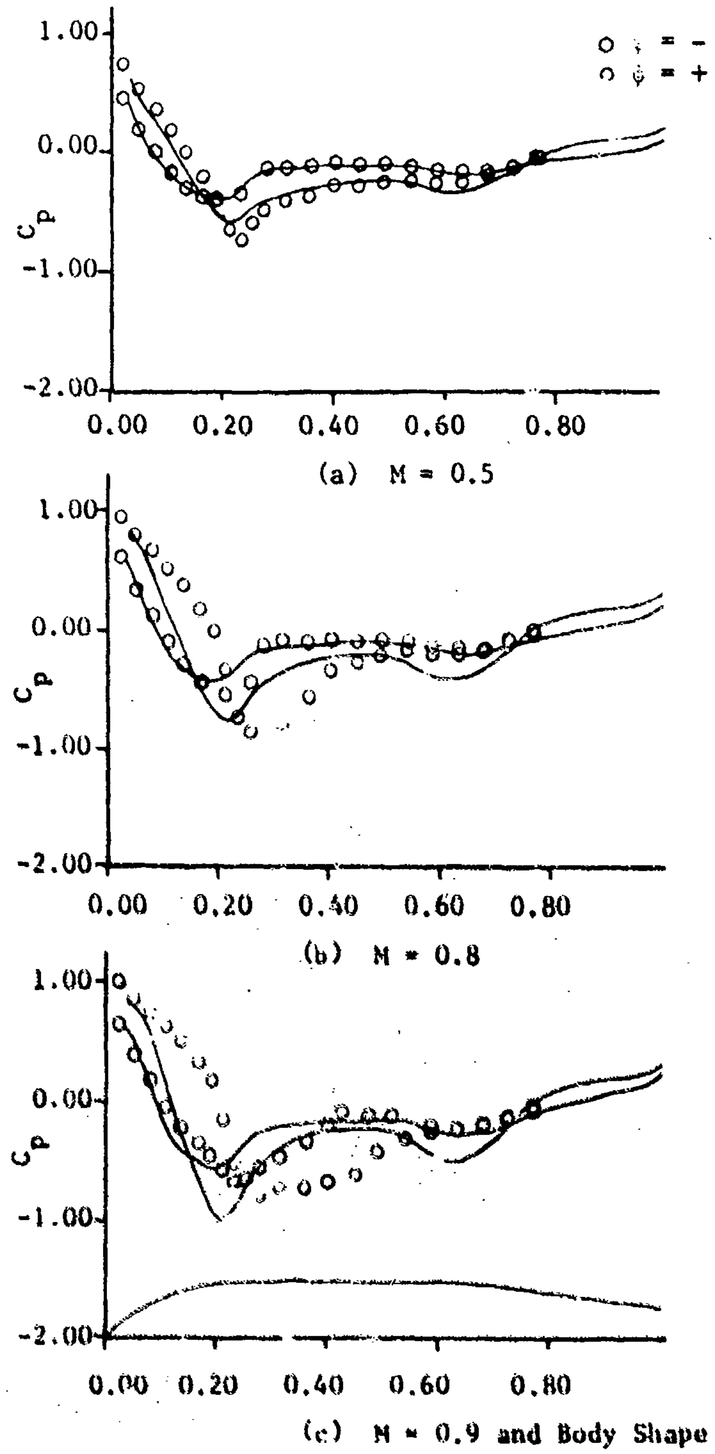


Figure 16. Comparison of Theoretical and Experimental Pressure Distributions for Mod M-117 Bomb Displaced to Z/D = 0.5 from TER Carriage Position No. 1, $\alpha = 0°$, $\theta = 0°$.

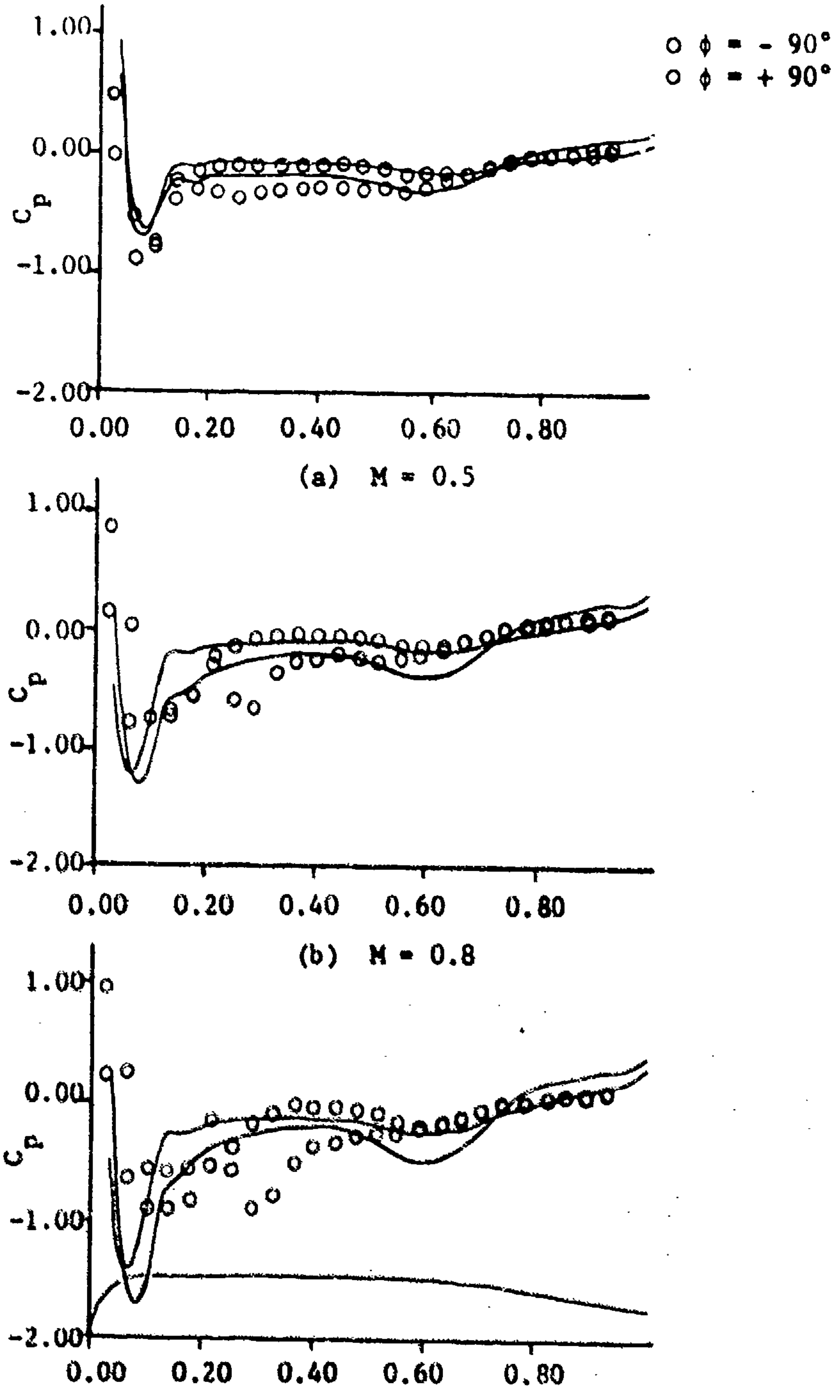


Figure 17. Comparison of Theoretical and Experimental Pressure Distributions for 16-Inch Maximum Volume Bomb Displaced to Z/D = 0.5 from TER Carriage Position No. 1, α = 0°, θ = 0°.

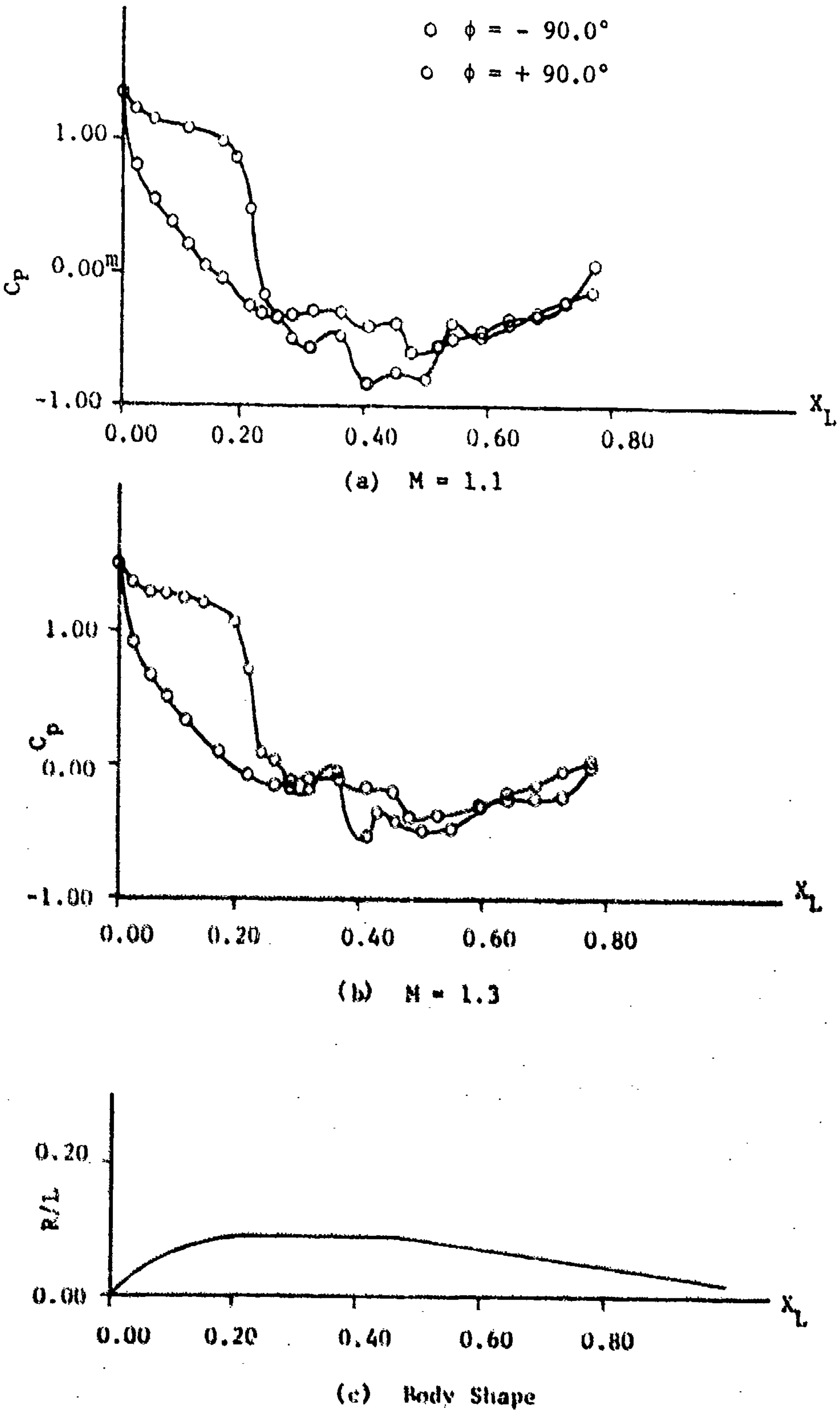


Figure 18. Pressure Distributions for M-117 Bomb in TER Carriage Position No. 1 in Supersonic Flow, Z/D = 0.0 α = 0°, θ = 0°.

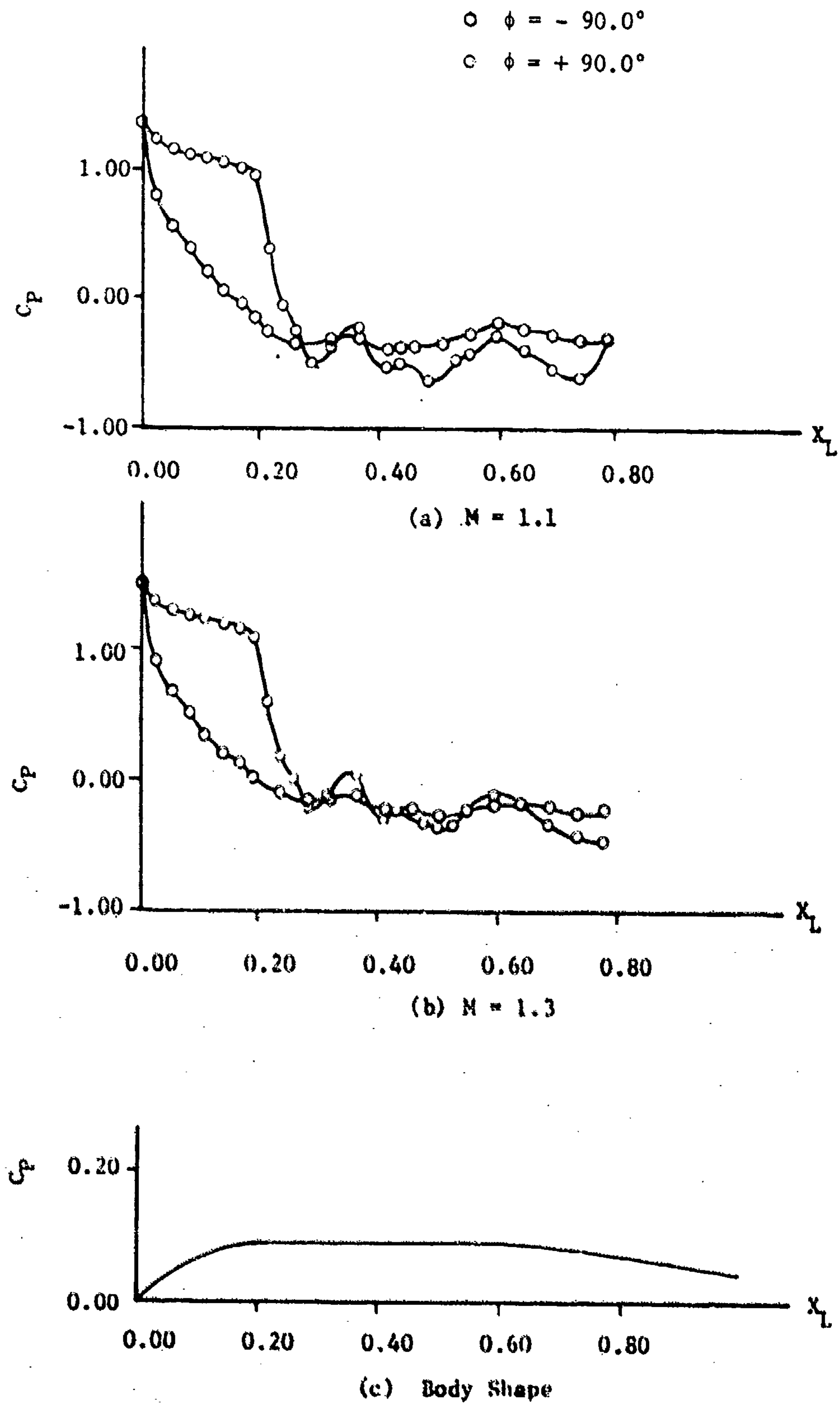


Figure 19. Pressure Distributions for Mod M-117 Bomb in TER Carriage Position No. 1 in Supersonic Flow, $Z/D = 0.0$, $\alpha = 0°$, $\theta = 0°$

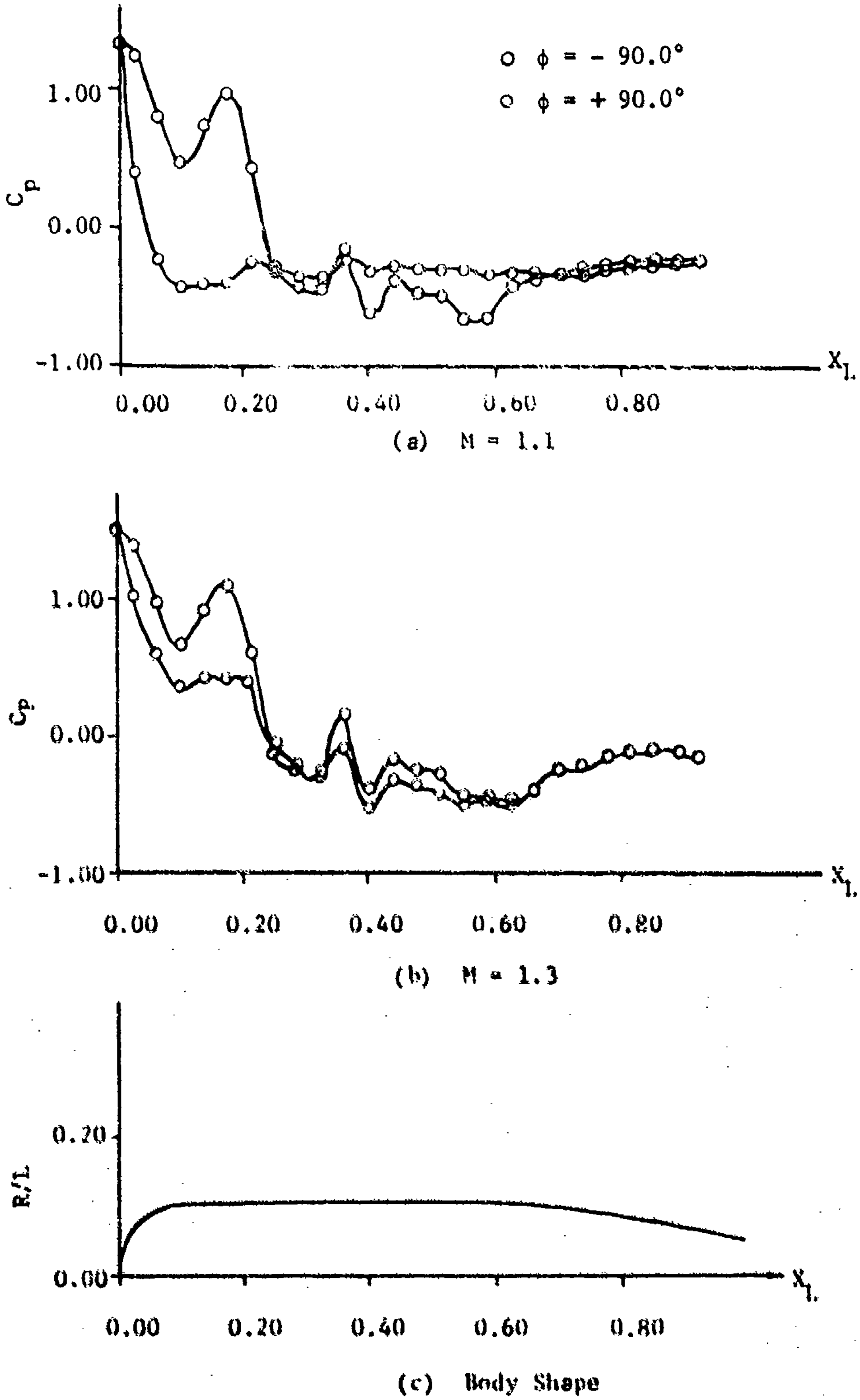


Figure 20. Pressure Distributions for 16-Inch Maximum Volume Bomb in TER Carriage Position No. 1 in Supersonic Flow, Z/D = 0.0, α = 0°, θ = 0°

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